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2025 is a study designed to comply with a directive from the chief of staff of the Air Force to examine the concepts, capabilities, and technologies the United States will require to remain the dominant air and space force in the future. Presented on 17 June 1996, this report was produced in the Department of Defense school environment of academic freedom and in the interest of advancing concepts related to national defense. The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

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Contents

Preface

We must ask where we are and whither we are tending.

—Abraham Lincoln

Not all the studies in ***2025*** could be categorized under the headings listed in volumes 1–3. Some did not depend upon the specific worlds of 2025 that had been forecast and used as the basis for the study. They did not fit neatly into the categories of technologies, systems, and concepts of operations. They lay outside the alternate futures assumptions, were more generic in nature, and, to some degree, were independent of the transformation of the world and the threats it might generate. These studies are included here in order to present the total range of topics investigated.

The studies in this volume are a mixture of specific issues, alternate futures of a different sort, and general circumstances that may well condition, if not determine, the world of 2025. In this way, the volume's first two papers—"Paths to Extinction" and " ' . . . Or Go Down in Flame?' "—serve as an internal validation mechanism and a "null hypothesis" for certain of the ***2025*** team assumptions about the future. It is entirely possible, for a variety of reasons, that there will be no USAF in 2025. We should thoroughly explore that possibility if we want the overall ***2025*** study to be objective and of real value to the USAF chief of staff in his deliberations about how best to plan for the world of tomorrow.

After the study group constructed the alternate futures and explored the various technologies and systems that could emerge in the next 30 years, the Operations Analysis (OA) team conducted an assessment of the technologies and systems that the study teams developed. The OA team employed value-focused thinking as the enabling methodology to score the various technologies and systems. This methodology, its results, and their comparison are explained in detail in the volume's third and final paper, "An Operational Analysis for 2025."

(Please note that appendix A contains a list of all the papers in the ***2025*** study, arranged by volume for ready reference. Also, appendix B contains a list of all the people—military and civilian, warriors and scientists, educators and operators, leaders and supporters—who contributed to the ***2025*** project.)

Paths to Extinction: The US Air Force in 2025

Dr Grant T. Hammond

Contrary to popular belief, people do not learn from experience. Rather, they respond to a particular stimulus in a deliberate way and thus predictably.

—Evan S. Connell
Son of the Morningstar

The fundamental purpose of all organisms and organizations is to survive and prosper. Anything that impairs one's ability to do so is a threat. Traditionally, military services have focused on threats to the nation and on potential adversaries in the next war. But while these are the focus of military planning, they are not the only—or the most important—threats to a military service or a nation's armed forces. There are many others, internal as well as external (e.g., political, economic, social, technological, and military). And the biggest threats may occur in peace, not war: It is the military preparedness and the superiority gained in peace that will spell victory in war. The relentless competition for more or better weapons, improved doctrines, and winning strategies may be the real competition, with war a form of public validation of peacetime realities. Given the increasing costs, lead times, and consequences of decisions about how to organize, train, equip, and fight in the future, we should take as much care in peace as we do in war regarding the security of both the service and the nation.

Though members of the United States Air Force (USAF) may be discomfited by the assertion, their service is in serious jeopardy of ceasing to exist in the not too distant future. For a variety of reasons, developed later in this paper, the continued existence of the USAF is anything but secure. Five years after its greatest triumph, the USAF finds itself besieged by orchestrated attacks from the other services. In a series of exercises and war games, arguments in the Commission on Roles and Mission of the Armed Forces (CORM), meetings of the other services and Congressional committee work, the USAF is increasingly isolated and criticized.

Both the Army and the Navy have sought to gain power, prestige, and budget share at the USAF's expense. The US Army, the Air Force's parent, has always bemoaned the loss of increasingly powerful air assets. It no longer possesses capabilities that it used to control. The USAF provides the Army both intertheater and intratheater mobility through air transport and additional striking power in the form of close air support. The Navy, the USAF's most consistent adversary since William ("Billy") Mitchell's destruction of battleships by aerial bombardment in the 1920s, has always sought to gain air (and later, Air Force) missions, be it long-range air defense, strategic attack, or power projection. Since the end of the Gulf War, both services have coveted Air Force assets and missions. The Army wants to control deep attack and manage an expanded battlespace while the Navy sees carrier naval aviation as the first line of defense and the ultimate in power projection. Both argue that missiles—the Army Tactical Advanced Missiles System (ATACMS), or a next generation follow-on system, and the Tomahawk Land Attack Missile (TLAM)—

can replace manned aircraft for conventional missions, thereby allowing each service to compensate for what it wishes to control.

On the heels of the Gulf War and the success enjoyed by USAF airpower, the joint force air component commander (JFACC) concept of air operations, and the success of a large-scale independent air campaign run on the air tasking order (ATO) system, several events have cast that success in a different light. The Army-Navy Joint Board's first meeting in nearly 60 years was held in November 1992 to discuss, among other things, how the Army and the Navy might better coordinate their planning. There was no USAF participation because the USAF was not invited. Exercise Atlantic Resolve, held in November 1994, was used to "prove" that a JFACC afloat concept could work and supplant an Air Force JFACC. There is a new Senate Armed Service Committee structure which divides defense issues under its review into Navy/Marine matters and AirLand matters. Such an arrangement ignores the fact that AirLand Battle was not primarily the way in which the Gulf War was fought. More importantly, all of these suggest a conscious attempt to degrade the value and validity of independent airpower as wielded by the USAF.

Worse, the USAF is assisting in its own demise. After struggling for decades to become independent, it finds itself in an era of jointness in which its unique capabilities and special talents, though demonstrated, are devalued. Under the guise of jointness, the mantra of the US defense establishment since the passage of Goldwater-Nichols in 1986, the US Air Force has sat by meekly and acceded to a circumstance which is increasingly debilitating. To the US Army, jointness means global mobility and close air support—things that it gets and the Air Force gives. To the US Navy, jointness means land-based aerial refueling of naval air assets and USAF combat air patrol in support of naval air assets attacking land-based targets. Here, the Navy gets and the Air Force gives.[1] The USAF, in the interest of jointness, has allowed itself to be directed by others. If one speaks up for the USAF, one speaks implicitly against jointness. And worse, if one speaks for jointness, it is often at the expense of the USAF.

The Argument in Brief

The USAF may well face extinction by the year 2025. If such a state of affairs comes to pass, it will be because of its failure as an institution to ensure its viability and evolve appropriately in a complex, uncertain, ambiguous environment, both at home and abroad. Given the contribution made by airpower in the Gulf War, largely wielded by the USAF, such an outcome seems sheer fantasy. But unless important issues are addressed promptly and well, this could soon become reality.

Institutionally, the participation of senior USAF leadership in US military strategy formulation and implementation has, with few exceptions, been studiously avoided. While there have been two chairmen of the Joint Chiefs of Staff (CJCS), from the US Air Force (Gen George S. Brown and Gen David C. Jones), there has been only one regional commander in chief (CINC) [Gen Lauris Norstad was Supreme Allied Commander Europe (SACEUR)—in the 1950s]. As of this writing, there are no USAF (CINCs) in a regional command. In a variety of settings—the National Training Center's modeling and scoring, the Navy's Global War Game in Newport, assertions in Roving Sands exercises, and notions of a Theater Missile Defense Tactical Operations Center as a separate operational entity—airpower's role is diminished. To ignore or dismiss the contributions of airpower in general is to ignore or dismiss the USAF in particular. Collectively, they create a climate which ensures that an airman's perspective is not a part of the conceptual formulation of national military strategy.

Many of these difficulties are of the USAF's own making. One of its greatest sins is a misplaced enthusiasm for AirLand Battle. That is Army doctrine, not Air Force

doctrine. The USAF, after gaining its hard won independence, willingly sacrificed most of the advantages it had obtained and served its Army masters once again.

> The Air Force has conceded the intellectual high ground to the Army with its AirLand Battle concept. While airpower must support the ground commander, it is limited to no more than that if the Air Force has no integrating concept of its own.[2]

Why did the USAF come under the spell of the notion of AirLand Battle? It is US Army Doctrine that was developed in the late 1970s and early 1980s. Having been seduced by atomic/nuclear deterrence until confronted with its second limited war in Vietnam, support for the Army was the only role for Tactical Air Command (TAC). TAC began wresting control of the USAF from the Strategic Air Command (SAC) and the bomber side of the USAF in the 1970s. "In 1960, bomber pilots held 77 percent of the top Air Force leadership positions, fighter pilots, 11 percent; by 1990 these percentages had become 18 percent and 53 percent respectively."[3] Thirty years from now, this ratio should be considerably different. The problem now may be how long it will take USAF to integrate nonrated missileers into the hierarchy and come to appreciate space—as a mission, an opportunity, and a place—in USAF thinking.

Not only most junior Air Force officers, but senior USAF general officers as well, saw the USAF role as supporting the Army. The legacy of Vietnam and AirLand Battle on the one hand, nuclear deterrence and the single integrated operational plan (SIOP) roles on the other, meant the USAF was somewhat schizophrenic about its mission. This was the result of the SAC versus TAC struggle for control of the USAF.[4] Air superiority was deemed critical but there were many who saw Air Force's principal mission as supporting the ground force commander and his scheme of operations, not necessarily the conventional strategic use of airpower such as we saw in the Gulf War.[5] In believing this to be true, these men were expressing the belief of the USAF at that time. No other service has thought so little of its own mastery of its medium of operations and combat potential. That reality is showcased in Col Richard T. Reynolds's book, *Heart of the Storm: The Genesis of the Air Campaign against Iraq*.[6] In its own mind, both prior to and after the Gulf War, the Air Force was to take notes from the land component commander and provide what he required.

Furthermore, the USAF finds itself having difficulty in supporting publicly defensible funding priorities. As the systems become more technologically advanced, the numbers required decline and the costs per unit increase. Thus, the B-2, the C-17, the F-22 (let alone space systems) are more difficult to defend. They are quite literally worth far more than their weight in gold—a concept the average American voter finds difficult to comprehend. The cost of space operations—$10,000 per pound to place things in orbit—and the cost of satellites, tracking capability, and so forth, are greater still and compound the problem still further. The procurement of each technologically laden system thus becomes more and more difficult with the next one always at risk.

Worse still, the failure to capitalize appropriately on its demonstrated success in the Gulf War—both internally within USAF and externally with the public at large—has squandered a once-in-a-lifetime opportunity to emblazon the image and capability of USAF and American airpower on the minds of a grateful nation. American combat forces had a casualty rate in the Gulf War lower than that of a 20-30-year-old male who remained at home on the streets of our nation's cities.[7] Rather than aggressively asserting its capabilities, the case for airpower—meaning both air and space capabilities—needs to be made quietly, effectively, and persistently.

Given this as background, the hypothesis is as follows: *Unless present circumstances and trends are reversed—and soon—the*

USAF will become extinct by 2025 *or soon thereafter.* It would no longer exist as a separate service, would have no sustainable rationale for an independent existence, and would find its roles, missions, and assets parceled out to others. It could be suppressed, abolished, or annihilated—all meanings of extinction. Moreover, this 2025 eventuality is being determined now because "Decisions made today have 30-year implications."[8] This could happen in a number of different ways. They divide into two separate categories of paths to extinction: externally caused extinction (the actions of others) and internally caused extinction (actions taken by USAF itself). We will examine each class of actions.

External Paths to Extinction for the USAF

There are essentially six different external ways in which the USAF could become extinct by 2025. They can be summarized as follows:

1) the ascendancy of other services,
2) economic and budgetary constraints,
3) a different set of defense choices in a constrained environment,
4) a transformation in the nature of war,
5) technology becoming the death knell rather than the savior of aerial warfare, and
6) the rise of jointness to its logical conclusion.

Each of these is entirely possible, some quite probable. The logic provided below shows how the extinction of the USAF could come to pass.

Other Service Ascendancy

There are three subsets of consideration here. The first of these is the ascendancy of the US Army as the backbone of America's defense. There has always been an Army, and its role in the nation's defense is central to our conception of war. In the minds of most Americans, America doesn't really go to war unless or until it commits ground forces to combat. Though much smaller than in the past, the Army will become more technologically adept. It will invest in a continuation of rotary winged aircraft, unmanned air vehicles (UAVs), and long range attack missiles. These weapons will encroach on the tactical and even the strategic missions of USAF. In seeking to digitize the battlefield, the Army seeks a portion of information dominance too.[9] It may well win the roles and missions debate, thereby winning the right to shape the deep battle.[10] In short, the Army's roles and missions will likely grow, not shrink.

In such an environment, the land component commander (LCC) will select targets, have increased numbers of ATACMs and other ground launched missiles at his disposal,[11] control the placement and movement of the fire support coordination line (FSCL) or its nonlinear progeny, and, with all these, the timing, location, implementation and lifting of joint fires. Aerial attacks will be tightly controlled by corps commanders who will see them as supportive of, rather than supported by, the joint force commander's scheme of maneuver. This is necessary, it will be argued, to prevent fratricide on the ground. Theater ballistic missile defense will become a major Army mission, and a tactical operation center for its control will work the issue as an Army problem and solution. Counterbattery fires are seen as relatively cheap, effective, and retaliatory, rather than offensive in nature, making them somehow more acceptable—if not better—to a reluctant Congress and a public whose sensitivity to clearly offensive systems is likely to grow.

In the second subset, the US Navy could emerge triumphant from the politico-economic contest for preeminence. Navy will be bolstered by its reactions to naval threats such as those by China against Taiwan. From the rise of carrier air in the 1940s through sharing the strategic nuclear mission with Navy submarines in the 1960s to the competition to be the ultimate power

projection force in the 1980s, the Navy has consistently whittled away at what USAF saw as its own missions. Though unstated, "SeaLand Battle" (as opposed to "AirLand Battle") is the doctrinal concept behind *Forward, From the Sea . . .* and its form of power projection. The US Marines are the light but unified crisis-deployable force with the Navy. And if we have to project a large force abroad, the bulk of it will go by sea. Although large numbers of troops went by air, 95 percent of the materiel sent to both Vietnam and the Gulf went by sea.[12]

The US Navy has a piece of all the action. It has global operational capability with nuclear powered carrier battle groups (CVBG) and submarines. It has tactical capability along the littoral (where most of the world's crises and major battles have occurred)[13] via carrier air, TLAMS, and surface action groups (SAG). It has the strategic mission with submarine launched ballistic missiles (SLBM), a crisis response capability with the US Marine Corps, and a host of systems—Aegis/ERINT (exoatmospheric re-entry intercept), antisatellite (ASAT) and theater missile defense (TMD) with which to protect the US and its interests. Despite the fact that the USAF supplies 90 percent of the people and 80 percent of the money for space operations,[14] the US Navy has its own fleet satellite (FLEETSAT) network. This is a very expensive service-dedicated luxury. The US Navy is selling the naval expeditionary task force (NETF) as the force of choice for the future.[15] The Marines have the best bumper sticker at the moment—"A certain force for an uncertain future,"—and the Navy has proved itself more adept at placing its officers in the joint hierarchy than the other services. Seventy percent of the earth's surface is covered by water, the US has broad ocean moats to the East and to the West, and the US Navy has over two centuries of naval tradition. The Navy also has better lobbies, a simple message, and a more coherent vision. Placing the defense of the nation in the hands of the US Navy has been traditional for much of our history. Doing so now and for the future seems even more appropriate—and likely.

A third way in which service ascendancy could destroy the USAF has historical precedent. Space Command is to the US Air Force today as the Army Air Corps was to the US Army in 1946. Space is laying claim as a separate domain with different problems and with different vehicles to operate in a different environment. Though a part of the third dimension, space has a different environment that requires different technologies and different operations. While vehicles that can fly in the air can fly in space, spacecraft can't necessarily "fly" in the atmosphere. The separate domain of space also has a different status and different constraints, given treaties and international agreements regarding it. The combination of divergent technology choices, massive budgetary support for space initiatives, and the political difficulty of trying to control both atmospheric and exoatmospheric to deep space—all suggest that the creation of a separate Space Force may be a matter of common sense and ultimate reality.

The costs of investments in space resources are enormous. Without some dual use by commercial and military sectors alike, massive amounts of money for research and development—let alone actual operations—seems unlikely to be forthcoming. There are numerous actors in space, both domestically and internationally, national and commercial. Space is obviously of crucial importance for security as well as technological advancement. But we can't afford separate systems for air and space. Why not, the argument goes, allocate air missions to the other service and turn the rump of the US Air Force into the US Space Force? The Space Force would focus on the arena of the far future Space.

A variant of this approach focuses on the rising importance of information dominance for military victory and suggests that we formalize much of what we do in space at the moment with the creation of an Information Command for conducting of

information warfare.[16] The combination of all information war roles and missions, many of which are focused in space, into a new entity appeals to the logic of centralized control of such assets for all the services. And indeed, the consolidation of military influence in the Office of the Secretary of Defense (OSD) seems headed in this direction. The Ballistic Missile Defense (BMD), the Central Imaging Office (CIO), Defense Aerial Reconnaissance Office (DARO), the Defense Information Systems Agency (DISA), and the National Reconnaissance Organization (NRO) all have OSD backing more than service ownership. All space-based multispectral data collection, data distribution, deception operations, and verification assets would be centralized; not USAF roles or missions. It would likely place civilians even more firmly in control, thus depriving the services of these capabilities—at least directly. In short, the USAF would remain atmospheric, not "infospheric," and the latter roles and missions would belong to a separate entity.[17] And, since the Army and the Navy are laying claim to USAF roles and missions, there would then be no USAF.

Economic and Budgetary Constraints

As long as the US economy does not falter badly, there is no real crisis. Downsizing, reorganization, and declining budgets will likely continue for the military, but not at crisis proportions. However bad it has been, the post-cold-war demobilization has been nowhere near as great as post, (World War I) or post (World War II) demobilizations. But the national and world economies are subject to a host of perturbations. For one thing, our money is not very secure. Sixty percent of US dollars are held abroad and the US cannot control their flows. Increased counterfeiting of US cash is a major weakness in our national defense. The counterfeit money is so good as to be virtually indistinguishable from the real, thus forcing us to begin issuing new currency. Our economy is at risk, too. Another oil shock, which could be caused by any number of events in the Middle East, could induce a global recession or even depression. This could be severe, given the economic difficulties of Japan and Germany—and it's more likely, given the rapidly rising debt of many of the organization of petroleum exporters (OPEC) states, particularly Saudi Arabia. Since there is, strictly speaking, no functioning international financial system, this could cause a banking system or currency crisis that would permeate the international community.

Our trade and financial systems are also at risk. Corruption—the human kind; for example, those who run the financial institutions and stock markets—or the electronic kind; for example, computer viruses that infect databases—could bring international trade and financial dealings to a standstill. Our impact on the world economy could be jeopardized in any of several ways. Withdrawal of foreign investment (from the US) in favor of other markets (Asian) with higher yields could radically affect world financial flows and market stability. Or a chain reaction of events, involving less than major actors, could panic currency markets. (When peasant unrest in Chiapas, Mexico, led to a fall of the peso, a massive financial assistance effort by the US and a precipitous fall of the dollar resulted.[18]) The lack of a budget agreement in the US for more than half a year is not a confidence inspiring circumstance. A lack of significant progress on the annual deficit and the national debt may cripple the US as the major financial actor in the world. While improbable at any one point, all of these are possible. They represent wild cards to US security, that is, they are beyond the military's control.

For some time now, the US defense budget has been a target of opportunity for budget cuts. Representing as it does the largest source of fungible assets in the federal budget in a given fiscal year, the DOD budget is a raidable asset. Amid the pressures discussed above, it could become an even bigger target of opportunity to a

Congress of the future.[19] This trend—of past practice, current reality, and increased future problems—exists at the service level as well. In the competition for increasingly scarce resources, USAF is the supporting, rather than supported, service. It has taken a greater percentage of the hits on its highly visible, very large systems.

> During the last half of the 1980s, cuts in the Air Force budget exceeded the combined cuts in the Army and Navy. Worse, because of mandated and protected programs, what was hurt most was the Air Force investments in the future. The Air Force lost $46 billion, while the other two services each lost less than $22 billion.[20]

Since the Gulf War, a review of service requests and Congressional budget cuts reveals a similar tendency: USAF cuts are nearly double those of the Navy; Army has lost the least in percentage terms. In the future, the need for near simultaneous replacement or continuing major upgrades of 1970s weapons systems and platforms in all services in the first decade of the twenty-first century will increase the pressure for scarce resources. The great majority of all the major weapons systems of the US armed forces date from the 1970s or earlier—and obsolescence gets worse as system life expectancies are extended. Many of the aircraft in the inventory are far older than the pilots who fly them.

The USAF may have severe problems as the numbers of each new generation of fighter or bomber shrink precipitously because of higher unit costs. Cost overruns on the F-22, continuing investment in space systems, and initial research and development for emerging technologies lead to having the operations and maintenance accounts besieged in the process. The B-2 phenomenon may become the norm; that is, one buys a squadron (rather than a wing) of particular systems to have them in the inventory, but in very small numbers. Each unit cost is then so high that the risk of aggressive training and actual deployment, let alone use in combat, increases dramatically because the loss of one could be catastrophic in the eyes of an increasingly budget conscious Congress and public.[21]

Policy Choices in a Changed Strategic Environment

It is entirely possible that the nature of the world we face and the threats to US security will become either so ambiguous or so novel that we lose the ability to respond effectively. Traditional problems—nationalist inspired civil wars, disputes over borders and resources, religious or ideological crusades—may mix with threats inspired by drug cartels, international crime syndicates, vendettas of wealthy individuals or corporations, computer hackers, resurgent communist regimes, renegade nuclear scientists, or organized international terrorism. Current trends may become even stronger. Social security continues to be more important than national security as a matter of social, political, and economic concern throughout the US and her NATO allies. Welfare is a more important problem than warfare in the minds of most. The 1990s are beginning to look more and more like the 1920s—a rising bull market, no peer competitor for the US, international organizations and agreements supplanting investments in military capability, the importance of trade and finance growing at the expense of politico-military concerns in the international arena. Who, then, is the military threat to the US? If there is none, then a return to a policy of isolationism—at least a military one with greatly diminished forward presence and power projection capabilities—becomes more likely.[22]

Increasingly, we are using military forces for military operations other than war (MOOTW). Doing so is appropriate in one sense—that is what militaries do in peace time. But it is inappropriate in another sense: If doing an increasing number of these operations simultaneously degrades our combat capabilities, it will not have been a wise choice. Performing MOOTWs with little or no chance of solving fundamental problems or increasing national security may

actually make things worse. In the. name of peacekeeping and humanitarian assistance, we are progressively reducing our military capability by intervening in a series of failed states. Solving particular problems, even if we could, might not lead to a significant enhancement of peace and security in any one region, not to mention the world in general.

The USAF is particularly vulnerable to declining readiness due to MOOTW in such places as northern Iraq (Provide Comfort), Somalia (Provide Relief, Restore Hope), Rwanda (Support Hope), Haiti (Uphold Democracy), Bosnia (Provide Promise, Deny Flight, Joint Endeavor), and future efforts to provide humanitarian assistance. In support of these operations, the USAF has nearly 50 percent of its fighters deployed overseas. Many of USAF's reconnaissance, transport, and tanker assets are deployed abroad—and four times the number of USAF personnel deployed abroad in 1989 are currently deployed abroad.[23] These "peacekeeping operations" cost billions of dollars, degrade combat skills, use up precious service life of military systems (especially bare base equipment), and seriously impair retention in both the active forces and the reserve and guard components of the military. Spending scarce military resources in this way may degrade them. Keeping the peace may promote insecurity when a test of force arises.

Technology May Well Prove the Death Knell of the USAF

As the service most closely tied to technological progress, the USAF may be particularly vulnerable when there are no airborne technological solutions to many of the threats that confront us. While war has become more deadly and costly in the West, the choice to initiate war is seen as uneconomical at best and suicidal at worst (even for the victors in some cases), the test of arms will continue to be the choice of some for the foreseeable future. And the means with which to wage war are such as to make conventional war irrelevant and other forms of war more horrible. The proliferation of conventional weaponry is bad enough; the spread of weapons of mass destruction, be they chemical, biological, or nuclear, may make us long for the bad old days of the cold war. By the end of this century, some 20 nations will likely have nuclear weapons.[24] These can be delivered as large or small weapons via missiles, planes, ships, torpedoes, or artillery shells. They could also be delivered by trucks, cars, packages or shipping containers—hundreds of thousands of which enter the US every day. Add the possibilities for chemical or biological agents—much cheaper, easier to manufacture and disperse, more difficult to detect, just as deadly and more difficult to combat and one gets a sense of growing risk.

The fruits of technology in things that do not go "bang" such as the global positioning system (GPS), notebook computers, direct satellite broadcast capability, sophisticated space-based sensors, increased bandwidth and the like, genetic engineering, possibilities for weather alteration, and particle beams—could dramatically transform warfare as well as societies. The investment in things that do bear on combat capability more directly—stealth technologies, lasers, improved munitions and guidance systems for them—make today's combat systems much more expensive and valuable assets. The investment in pilots and their planes is such that we may be loathe to utilize them. High-tech solutions to low tech adversaries are not cost-effective, as the Soviets found out in Afghanistan (they used MiG-29s against the mujahideen's goats carrying supplies in the mountains). Worse, contrary to Douhet's assertion, air superiority may be neither necessary nor sufficient to win—as both Korea and Vietnam should have proven to the US. If the USAF can't protect US citizens and win the wars the nation has to fight, and if technology costs continue to increase, the citizen might well ask why we need a USAF. Technology may not be our salvation and USAF pilots may go the way of their

forerunners—the well-armored medieval knight.

The Nature of War and Warfare Is Changing

Equally important is the ambiguity of the present and future security environment. Who, or what, is our adversary? Increasingly, the threats to national and international order both here and abroad are coming from what we might call nontraditional adversaries—international crime cartels, domestic terrorists, multinational nonstate actors, drug lords, international business and economic espionage, large numbers of refugees fleeing economic, social and political oppression, the international transmission of disease, and simple, everyday, corrosive corruption. Investment in expensive and sophisticated space-based systems seems even less appropriate than it really is. What would the air campaign look like against these threats? What results could be expected?

Urban blight, decayed infrastructure, failed welfare programs, inadequate education, fouled air and water, rampant population growth, environmental degradation, species depletion, and a host of other problems are serious threats to security. But they have no traditional military solutions—at least none that are acceptable to an American in the last decade of the twentieth century. For those insidious and covert threats, how does one use military force to alleviate their symptoms if not defeat them? If terrorists act without claiming responsibility, against whom do we retaliate? All of these make the military case for national security more difficult, to fund and preserve. It may be particularly difficult for the USAF; how does one employ an F-22 against any of these?

Wars in the future may be radically different from those to which we are accustomed—and they could run a wide gamut of possibilities. They could be high-tech information wars among nonstate actors using nonlethal weapons, leaving little collateral damage and no "finger prints" (or leaving false ones) of responsibility. Or, they may be more primitive affairs, reminiscent of the Camp of the Saints[25] scenario in which masses of human beings with nothing to lose migrate toward those who do and bodies replace bullets as the weapons of choice. How would the West respond to hordes of barbarians at the gates of civilization? There could be warfare among highly specialized, loosely organized technological elites, not in uniform, who conduct campaigns by telecommuting. Or, there could be increasingly little societal interest in military issues as more and more of society's energies and resources are absorbed by problems within; for example, crime and punishment, law and order. And, some form of confrontation between the over-30 rich and the poor but angry global teenager seems likely.

Jointness "*über alles*"

For better or worse, jointness is now the mantra of the American military—as if repeating it endlessly will make it a reality. It is seen as a universal good, above reproach. To reject jointness is to be selfish, not a team player, part of the problem rather than part of the solution. The rather desultory and marginal report of the CORM did not make much headway in addressing the fundamental issues. One of these is that jointness means different things to different services. To the Army, jointness means it gets additional artillery in the form of close air support and global mobility in intertheater lift and intratheater lift—neither of which it has to pay for, maintain, or sustain. For the Navy, jointness means aerial refueling from land-based tankers for carrier air, and USAF-provided combat air patrol (CAP) and airborne warning and control system (AWACS) to allow Navy planes to strike their land-based targets.[26]

For the Army and the Navy, jointness is a paying proposition—literally and figuratively. They get and the USAF gives. For the USAF, jointness means it is always the supporting, never the supported, service—save for the

anomaly of the Gulf War. But that is not likely to happen again because the Army and Navy (and certainly the Marine Corps) will not permit that sort of independent air campaign to be fought again if they can help it. (The last Roving Sands exercise began with a Marine JFACC.[27]) But the insidious effect is even worse. The Army-dominated J-6 has decreed that the very words "air campaign" are now no longer to be used. There is to be only one "campaign"—the CINC's. Air operations are to "support" the campaign, and the term *air campaign* is prohibited. One wonders just how "Instant Thunder," the air campaign for the Gulf War, could have been described and how it could have emerged if it had had to be sold not only to a reluctant USAF but to a reluctant CINC.[28] Since J-7 has authority over professional military education (PME), the term and the concept will ultimately be driven from the education and training of the US military. What, pray tell, are students at the Air Command and Staff College (ACSC) supposed to do in their 10-month school if they no longer can learn to develop and employ air assets in an air campaign?

The fact that jointness is enshrined in legislation in the form of the Goldwater-Nichols bill makes it more difficult to overcome. A major result of the legislation is the emasculation of the services as well as their civilian secretaries. The Office of the Secretary of Defense (OSD), an increasingly civilianized and joint bureaucracy, watches carefully to ensure that service competency is not raised above the level of joint considerations. Perhaps more cynically, but accurately, Goldwater-Nichols was firmly embraced by the military because it guarantees each service a piece of the action every time there is a crisis deployment or employment.

Leadership has become management and jointness is the company way. Jointness guarantees that those who are most politically astute, rather than militarily adept, run the show. The joint requirements oversight council (JROC) decides the allocations. The individual services have the mission to organize, train, and equip their respective forces. The chairman oversees all, with the regional CINCs doing the planning, Congress doing the funding, industry doing the lobbying, and the major commands (MAJCOMs) carrying out the mandates with little correlation among them.

The investment in jointness, intellectually and operationally, is diluting the importance of airpower. Increasingly, the incentives for service competency are being sacrificed on the altar of jointness. The concept of joint fires is restricting and limiting the effectiveness of airpower. The surface forces, in the name of jointness, argue about the *processes* by which the war is conducted. The USAF, alone, is more concerned about strategic *effect* than the process. And the USAF has the most to lose because its very identity is enshrined in the concept of the independent application of airpower for maximum strategic effects. Consider these scenarios: Not having USAF regional CINCs, the JFACC being hobbled with a joint targeting review board (JTRB), having the other services guaranteed a right to support from USAF assets, abolishing the term *air campaign* from military usage and deleting it from PME—all in the name of jointness—virtually guarantees that air campaigns will disappear. Can the USAF be far behind?

It is extremely unlikely that all of these scenarios will come to pass. That any one of them could occur is, however, not far-fetched. Indeed, some combination of them is entirely plausible, perhaps even probable. Any one could be sufficient to cause the demise of the USAF. Strong tendencies toward several could do the same, whether or not they were fully realized. The USAF is likely to be besieged in the foreseeable future by threats to its very existence. Fending these threats off will take time, energy, and skill. The USAF may, or may not, be up to the challenge.

Internal Paths to Extinction for the USAF

In addition to these general external circumstances which could lead to the extinction of the USAF, there are other, internal possibilities as well. In these, choices made by the USAF itself might actually promote or even ensure its own demise. Thus, even if it copes successfully with the external circumstances suggested above, it could well be responsible for its own demise. The internal causes of extinction are as follows:

1) The USAF loses its sense of vision and its mission.

2) The USAF mismanages its people.

3) The USAF mismanages its programs.

4) The USAF chooses the wrong path for the future.

5) The USAF is too good at strategic warfare.

6) The USAF fails to adapt appropriately to the changing strategic environment.

We will examine each of these in turn.

The USAF Loses Its Vision and Mission

The USAF may be pulled in so many directions under the mantle of jointness, the need to perform and sustain multiple MOOTW missions, and the effort to maintain combat-ready pilots and planes, that it loses sight of its fundamental mission—the employment of air and space forces in defense of US national interests. It could do this in a number of ways. It could emphasize training to the detriment of its overall capacity to deploy and employ its force in the quantity needed. Alternatively, it could become so consumed with the multiple MOOTW missions it now has and may get in the future that it sacrifices training and readiness to operational missions. Thirdly, it could try to do everything everyone else wants it to do rather than refining and honing its fundamental skills to do what it needs to do, thereby becoming incapable of doing anything well.

The potential reality of this is not hard to grasp, given the number of current operations and their magnitude. As of 3 April 1995, the USAF had flown over 18,000 sorties in Deny Flight/Provide Promise in Bosnia, over 2,600 in Haiti (Maintain Democracy), over 146,000 in southern Iraq (Southern Watch), and nearly 66,000 sorties in northern Iraq (Provide Comfort)—all told, more than three times the number flown in the Gulf War. USAF has had nearly 50 percent of its fighters deployed overseas continuously, has managed 45 satellites on orbit, and has had security assistance personnel deployed to 101 countries in the two years since 1993.[28]

Perhaps most important, the USAF risks losing sight of its wartime duty and misunderstanding the nature of its peacetime interwar commitment—preparing for the next war and thinking about how it ought to be fought. If it continues its habit (and that of the American military in general) of always winning and never losing its own war games, of grading exercises on how smoothly they run rather than what is learned, of being more concerned with demonstrating success than learning from failure—in short, of being more concerned with self-promotion than with serious critical analysis and creative synthesis for future operations, then it is in serious trouble.

The USAF at times is its own worst enemy. In some of its official functions, portions of the USAF seem to prefer laudatory public affairs announcements, if not sheer propaganda, rather than even-handed objectivity.[30] Worrying more about self-promotion than self-examination is a failure to understand the problems confronting the USAF. Unless or until the USAF is seriously concerned with doctrine, with the uniqueness of airpower, with the understanding of the men and women in blue suits about what they contribute as a service and what makes that special, then there is no real identity, no real self-confidence, and no vision for the

future. Organizations that lose a vision of the future . . . die![31]

The USAF Mismanages Its People

The USAF has had the image of being a rather high-living (and air-conditioned) service, accustomed to better quarters and more creature comforts, and having stronger support and morale services than found elsewhere in the American military. Air Force enlisted dormitories, for example, put the rather Spartan quarters of their Army, Navy, and Marine counterparts to shame. The Air Force keeps pilot retention up "retention bonuses"—$30,000 up front after eight years of service—and $6,000 per year for five years between the 9th and 14th year of service, or $60,000 total. In treating its people well, and in using cash inducement and expensive perks, USAF may price itself out of business.

Despite the arguments made for "quality of life" issues, there is really no need for the USAF, or the military in general, to be in the commissary and exchange business in continental United States (CONUS). Nor is there compelling reason to support the hospital and medical facilities and numbers of personnel that we do. These were designed for mobilization in wartime, but are utilized increasingly in peacetime by military retirees. Nor is there need to maintain an infrastructure, despite three rounds of base realignment and closure (BRAC), that is still far greater than our needs. Keeping the military separate from the society it serves—in housing, recreation facilities, and much of the routine of everyday life—from gas stations to fast food franchises on base—may be counterproductive in the long run. Being seen as well paid mercenaries to do society's dirty work is not an image to promote. Nor is it a wise role to play, however, advantageous in the short term.

There are two points to be made here. First, the USAF is far ahead of the other services in reorganizing, downsizing and restructuring itself. That is both good and bad. Though it is not yet enough, it has taken far more cuts in the BRAC process than the other services. As of early 1995, 71 percent of all the BRAC savings were a result of USAF base closure and realignment activities. However, though USAF force structure has been cut by more than 30 percent, infrastructure has only been cut 15 percent.[32] But being, or appearing to be, a good citizen may not be a wise bureaucratic strategy; it is bases and jobs in congressional districts which keep the services powerful. As the services shrink, they have less power and leverage on individual members of Congress. If the bases, posts, ports, and other installations of the military should ever be assigned to the CINCs (the logical extension of Goldwater-Nichols), then the USAF is dead because it has had only one CINC since WWII. It would lose out easily in competing with the other services in such a system.

There is something radically wrong with the USAF when an Air Force general officer boasts that "we have more nurses in the Air Force than we have fighter pilots."[33] That is not what the USAF is about. The ratios of officers to total enlisted force (nearly one to four), or of general officers to fighter-wing equivalents (15 to 1), to satellites (6.5 to 1), to squadrons (1.4 to 1) or to Primary Aircraft Authorized (one general officer for every 13 planes)[34] have grown out of all proportion to the need. Colonels used to be wing commanders. Now, that is a job for brigadier generals. Such "grade inflation" serves to make the USAF more top heavy, not leaner and meaner.

The intense competition for senior-level slots means one has to be tagged as a captain for senior leadership and be promoted below the zone routinely. Those who have been well trained and educated in the officer corps (half of whom have MAs or MBAs, 1.5 percent of whom have PhDs)[35] and are not selected below the zone may take their training and education and go elsewhere, thus increasing the costs to the USAF by driving down retention rates. For

those who stay in, one may be more concerned about playing things safe than by being bold and innovative. While the officer corps has been assured that it is not a "one mistake" Air Force, the competition is so fierce, this may be the perceived reality if not the intent. It is not wise for an armed service to select out the risk takers and reward the risk averse.

The USAF Mismanages Its Programs

Cost overruns for major aerospace defense systems continue, making a jaded Congress and public even less supportive than they normally are. One observer has stated that if you multiply the original cost estimate by pi (3.14), you are generally closer to the cost of the deployed system.[36] While we built tens of thousands of one type of plane during WWII, and thousands of many types during the cold war of the 1950s and 1960s, we bought hundreds in the 1970s and began to buy only scores in the 1980s and tens in the 1990s. Norm Augustine's famous prediction—that sometime in the next century, the US military will be able to buy just one tactical fighter aircraft to be shared on different days of the week by USAF and the US Navy—seems to on the cusp of coming true.[37]

Several things are at issue here. A public that doesn't know about the defense budget but does care about its tax dollars is led to the erroneous conclusion that cost overruns are examples of fraud, waste, and abuse. That public demands that something be done. In response, we expand the auditing and cost control systems in use. This means that more and more people are keeping the books while fewer and fewer are minding the store. Quantity and quality of procurement—of platforms, weapons systems, munitions, services, people—are all threatened by the general atmosphere of waste.

Acquisition, logistics, and comptroller career fields are increasingly civilianized. Specially trained civilians are becoming their own stovepipe in the system, complicating things further and separating the operators from the procurers. Concentration into fewer players and larger contracts is becoming more of a reality as the defense industry downsizes, merges, and realigns. One result is an increase in single sourcing which creates a faster revolving door of military officers retiring into defense contractor and "beltway bandit" jobs as the number of government contracts shrinks and their significance increases. Whether the Department of Defense (DOD) is purchasing weapons systems or war games, technological advice or other "knowledge" via the Defense Advanced Research Projects Agency (DARPA) or Net Assessment (NA), the public is left with the impression that a lot of money is being spent on things they don't understand and that the money goes to the same circle of people. It is, at the very least, not good public relations.

As things get worse, with a defense budget that is stagnant or likely to fall and the USAF losing its share of those resources, hugely expensive new systems (e.g., the F-22) may never be acquired in sufficient numbers to replace existing capabilities. The solution, as shown first with the F-117, then the B-2 and perhaps the F-22, seems to be to buy fewer and fewer numbers as unit costs increase. As a steady diet, this "solution" is ruinous.

There is a certain quality in quantity—and having too few of what is needed, regardless of superior capability, is tantamount to defeat by a different route. The USAF, more than any of the other services, is technologically dependent; it procures very expensive systems. It is vulnerable to making a procurement choice from which it—and the nation—cannot recover. The cancellation of expensive aerial systems, as was done with the B-1A, in order to purchase the ill-fated B-1B, and with the Navy's A-12, and the preoccupation with technology demonstrators such as the joint advanced strike technology (JAST) program may become the wave of the future. There are many routes to obtaining a hollow force.

The USAF Chooses the Wrong Path for the Future

The USAF is wedded to the manned air-breathing airplane as the essence of its being. It disdained research into ballistic missiles and canceled the first contract for them in 1950. USAF took a long time to pursue the notion of cruise missiles, and then only if they were launched from aircraft. It has, until relatively recently, largely shunned UAVs. And despite the formation of Space Command in the USAF in 1982—25 years after Sputnik, 13 after Neil Armstrong walked on the moon, nine years after Skylab was launched and one year after the space shuttle Columbia first flew—the USAF has yet to integrate space successfully into its thinking as well as its operations.[38] Most visions of future air war contain a massive emphasis on UAVs. But it is difficult, perhaps impossible, for the knighthood of pilots that run the USAF—first from SAC then from TAC and now merged as Air Combat Command (ACC)—to accept the reality that the era of the manned air-breathing aircraft may eventually end. We should seriously consider the implications now.

As the images of the Gulf War fade and the likelihood of repeating such an air campaign declines, the USAF is less able to demonstrate its combat utility and necessity. And since Saddam Hussein's air force either refused to fight or fled the country, very few pilots had any aerial combat in the Gulf War. For the bulk of the USAF, it has been 24 years since it had to deal with the reality of mortal air-to-air combat in Vietnam. The public, and increasingly the congressional, image of airpower as utilized in Somalia, Rwanda, and Bosnia is that of aerial "truckers" who deliver gasoline to other planes in flight and to people and supplies around the world. It is the "Federal Express" of the military, delivering anywhere in the world—absolutely, positively, overnight—and, in the minds of many, little more. When combat aircraft are used, it is often passively, as in Deny Flight, or with tragic results—the shootdown of two US Blackhawk helicopters in northern Iraq in Provide Comfort. The great publicity success of recent times publicized a failure—the shooting down of Capt Scott O'Grady over Bosnia.[39]

Because of the many competing pressures for increasingly valuable and scarce assets, the possibilities for critical disinvestments in them increases. Keeping a balance of physical, financial, and human capital for the future is extremely difficult in the ambiguous defense environment in which we find ourselves. And the consequences of choosing wrong are enormous because there may be no second chance. Increasingly, wars are come-as-you-are affairs without years to mobilize, build up the output of the "arsenal of democracy," and bludgeon the enemy into submission by attrition and massive industrial output.

The wars of the future may well be short, sharp, limited affairs; longer insurgencies; nuclear, chemical, or biological contests—or even ones characterized by nonlethal weapons. Whatever they may be, one needs to be making important choices now for a not too distant future in which such an array of threats is a demonstrated reality. The USAF may not be institutionally able to choose intelligently among competing objectives and capabilities. It might well spread itself too thin or, worse, make no choice. Such a fate could spell the end of independently organized and controlled airpower.

The USAF Is Too Good at Its Fundamental Mission—Strategic War

For most of the period known as the cold war, the primary mission of the USAF was strategic nuclear deterrence. It became so committed to nuclear deterrence that it nearly forgot its conventional strategic war-fighting and war-winning role.[40] The Gulf War proved that USAF was uniquely capable of fulfilling the conventional mission as well. That, and the end of the cold war, has made the conventional strategic mission paramount in the eyes of many. But there are some problems; the USAF may be too capable for its own good.

There is little doubt that the USAF could punish severely, if not destroy quickly, nearly any target or set of targets anywhere in the world within a reasonably short time. It could do so with nuclear weapons or with conventional ones. An airborne horror of chemical, biological, or fuel air explosion could be visited on adversaries if need be. The problem is that it is not likely to be permitted. The US is self-deterred from ending, a war by using the winning weapons at our disposal.

Even going to war in the Gulf—a blatant case of aggression by an unsavory dictator of a loathsome regime against a small and weak neighboring state, with control of a large segment of the world's oil-production at stake and a continuing threat to Saudi Arabia and other oil-producing Gulf states—was difficult. It took six months of political preparation at home as well as abroad, in addition to a massive military buildup, and 12 UN Security Council resolutions to validate the righteousness of the crusade, before a very close US Senate vote permitted military action. A change of three votes would have meant the resolution to use force in the Gulf would have failed.[41]

Another legacy of the Gulf War is a strong sensitivity to casualties.[42] Even if we found ourselves having to fight a morally supportable traditional war in which there were large numbers of civilian casualties in urban environments, this would be increasingly unacceptable not only to Americans, but to much of the world at large. The American public is sensitized not only to collateral damage and numbers of casualties for its *own* forces but for those of the *enemy* as well. Too many casualties are simply unacceptable. Just what the threshold is cannot be determined in advance, but an adversary who can cause large casualties and/or a lengthy struggle is relatively advantaged when the center of gravity for the United States is American public opinion. Indeed, such attitudes are now ingrained in the US military. We have already had instances in which high-ranking members of the US military have uttered such statements as "No target is worth the loss of a plane and pilot"[43] and "I've buried my last Marine."[44] Even the US military may be becoming repulsed by the basic stuff of war—blood, death, and destruction.

The USAF, and the nation, still carry the burden of the two atomic bombs dropped more than 50 years ago on Japan. While there is no question of the awesome offensive striking power of the USAF, conventional as well as nuclear, the utter destruction it could cause may be morally unacceptable, both at home and abroad. Quite simply put, a Douhet-like "knockout blow" from the air may be an unacceptable way to win future wars to both our public and others. As the Tofflers characterize things, we are in need of brain force, not brute force, to fight and win future wars.[45] "Breaking things and killing people" to win a war if it is absolutely necessary may be permissible, but only in very small numbers and for very short time periods. We may be entering an era in which deterrence no longer works against our would-be adversaries who will happily risk martyrdom for their faith, religious or political. We may deter ourselves from using the weapons at our disposal because of the death and destruction necessary to "win."

The USAF Fails to Adapt to Changing Realities

Ultimately, the reason for the extinction of any species is failure to adapt. The adaptation of an organism, difficult though it may be, is probably less problematic than the adaptation of large-scale, complex organizations. They must assess things correctly, review a range of alternatives, select the best course of action, then ensure that it is implemented fully. Evolution for most animals occurs over generations, centuries, and millennia; organizations may have a few years, decades if they are fortunate, in which to adapt.

The strategic environment and its correct assessment must be reinforced with appropriate objectives, matched with the

necessary resources, and blended with the requisite leadership in order to adopt the correct strategy. Along the way, there must be an implicit harmony among these and the doctrine, technology, values, and organization which undergird them. Weaving this tapestry is a very difficult task. It is this type of thinking that is most difficult and rare. It is far more important than solving operational problems in an air campaign. The US military in general, and the USAF in particular, usually does not suffer bright, iconoclastic thinkers well or for long.[46] John Boyd, Dennis Drew, Tom Fabyanic, Al Gropman, John Warden, Ted Warner, Barry Watts, and many others retired as colonels or lieutenant colonels—and many were lucky to get that far.

Such talent, as is, available is often unidentified or misutilized. Few of USAF's best or brightest become general officers—and those general officers who know, care, and try and do something about, USAF's problems often have to fight their colleagues as well as the defense establishment to succeed. The USAF simply must become more adept at permitting and promoting those who think conceptually, critically, and creatively. USAF leadership must permit bottom-up thinking, not merely top-down directives. It is on the edges of an organization (or an organism) that one first senses change and tries to respond to it. Those at the center and top of the hierarchy, charged with charting the organization's future, need the best advice and talent they can get. For the future, the organization needs educated people who are morally sound, operationally adept, and technologically and politically capable. That means fostering insight, imagination, innovation, and integration—words not normally used to describe the USAF.

The Bottom Line

There are at least 12 paths to extinction for the USAF in the next 25 to 30 years. These are *not* chimerical future threats. All either exist or could appear relatively quickly and easily *now*. Only half of the threats are external to the USAF itself and, hence, beyond its direct control.[47] But at least half are *within* its span of control—indeed, its jurisdiction—if its leadership will face them. What is at stake is the death of the USAF. *The only real question is whether we are discussing a homicide or a suicide.* Any one of these 12 scenarios is possible, perhaps even probable. The odds that some aspects of nearly all will come to pass are better than ever. The likelihood that the USAF may escape any one is reasonable. The likelihood that it can escape them all is quite remote. The odds are that one or more of these event paths will occur; and that could lead to end game—extinction of the USAF by 2025.

Of the 12 possible paths to extinction outlined above, all but two are domestic in nature, and, hence, within our control to some degree—even though external to the USAF. The external causes of USAF's causes of its demise—other service ascendancy, economic and budgetary constraints, defense choices in a constrained environment, and the rise of jointness—are matters of domestic decision making, as are the USAF's internal choices and actions. The only two that lie outside the US itself and can be manipulated by others are the transformation of war on the one hand, and technology becoming part of the problem on the other. These are not really novel in that the evolutions of warfare and technologies are constants for everyone on the planet. But the US may not be able to control them.

What is crucial about them is our understanding of these processes and their significance. Knowing that these are important—and investigating, debating, and refining our arguments about and interpretations of them—is the first step in understanding how to respond and how to shape these forces themselves in the future. Knowledge—of our problems, ourselves, our likely adversaries, our capabilities, our objectives, the risks, the costs, the consequences of alternative courses of action—is

the key. Knowing as we do what the pitfalls are, it should be easier, though not guaranteed, that we can avoid them by creative adaptation.

Airpower possesses certain characteristics, elaborated below, which make it capable of reaching or striking quickly, from a distance, any place on the planet with great strategic effect. It possesses air and space assets which give it global awareness, reach, and power. These are central to deterrence, and both offensive and defensive capability. Airpower as wielded by the USAF has been central to the defense of the nation for half a century. And our reliance on air- and space-based systems is growing, not diminishing. The capacity for mass and maneuver, the versatility of air and space assets, the advantage held by controlling the ultimate "high ground," are indispensable to US military dominance. In possessing the world's largest and best—indeed, the only "full-service" air force—the US has invested much of its security in the capabilities wielded by the USAF both in war (strategic attack) and peace (OOTW and deterrence). To disinvest in airpower would be to place the nation at risk.

Extinction of the USAF might well mean extinction of the US itself. Without a USAF, the nation would lose its most formidable, longest range, most responsive, most versatile, global combat capability. If the USAF were to become extinct, the US would lose a major set of core competencies—and their integration into an effective combat force for deterrence, defense, or attack. It would lose those things that make airpower unique and the advantages that independently controlled airpower bring to the nation. It would lose full service, global awareness, reach, and power. Most importantly, it would lose knowledge, responsiveness, versatility, and the capacity for discriminate power projection through both mass and maneuver. Without them, the nation would be at risk. *For the good of the nation, we the citizens of the US and the USAF cannot permit this to happen.* How, then, do we go about avoiding it?

The Primacy of Airpower

The first answer to the question posed above is that we must have a better understanding of airpower, its unique attributes, the nature of warfare in the third dimension, and the implications of these for the conduct of modern warfare. *The only element common to all the paths to extinction is the failure to understand the significant attributes of airpower.* Understanding how it can be deployed and employed in service to the nation—better, faster, farther, with fewer casualties, greater precision, and less collateral damage than other forms of power—is critical. Judged by these criteria, it would be foolish not to understand the airpower attributes we now possess and to diminish, exhaust, or destroy them, given their value to national security. At the moment, however, neither the public, our political leadership, nor, sadly, many in the USAF itself, have the necessary understanding to utilize this rare commodity in the most effective ways.

Airpower is a unique form of power. It is, thus, one word, not two. Airpower is the term which refers to the third dimension—what is up, vertical and above. It includes space as well as the atmosphere. But it is still called "airpower" because the attributes of operation in the third dimension are similar, though the vehicles which operate in the arena of air and that of space may be different. Air is not space, but they are part of the realm of the third dimension what is above the earth's surface. The third dimension is the medium of airpower—both air and space. Airpower is characterized by a combination of attributes:

1) perspective,
2) speed/tempo,
3) range,
4) the combination of mass/energy and maneuver, and
5) versatility.

Appreciating each of these in turn, what they mean to our capability in air *and*

space—and *in the aggregate* as airpower—is absolutely vital to understanding the importance of airpower—and the existence of the USAF—to the United States.

Perspective

Perspective is what airpower provides from the vantage of the third dimension. It fulfills the wish of commanders from time immemorial "to see the other side of the hill."[48] *Put succinctly, the advantage of airpower in the first instance is its vantage.* The view from the third dimension, the distance one can see from height, the cone of view that is included at higher altitude all the way to geosynchronous earth orbit at 23,000 miles away, is unique to airpower and lies at the heart of what it can do that surface forces cannot. From height and perspective, one gains vantage. From vantage, one gains global awareness—the ability to observe the surface of the planet in greater or lesser detail from the perspective of the third dimension. That in turn conveys a form of global presence and, hence, awareness through air and space assets. Global awareness, in turn, enables global reach and global power. These are what airpower brings to the fight and the joint force commander.

The importance of vantage cannot be overestimated. The perspective of the third dimension conveys a presence which is a prerequisite for global view. Global awareness conveys the knowledge that is the basis for decisions about alternative courses of action. *Knowing what is going on in near real time is the prerequisite for providing security.* Airmen call it situational awareness. Having others know that enhances our deterrent capability. Aerial or space-based presence, even episodic presence, can substitute for forward deployments of other forces, thereby diminishing the logistical problems of transportation and sustainment and the risk of human lives in large number. And much of our space-based presence is on station with multispectral sensing capability which greatly enhances our ability to see, hear, and know what is happening around the world.

Control and exploitation of the third dimension—air and space—provides us with the capability to engage adversaries from on high, from afar, and through a variety of methods of attack that run the gamut from communications jamming and target designation to bombardment via laser guided munitions, infrared sensor missiles and eventually air- and space-based lasers. The quantity and quality of information gathered and dispersed through the third dimension—increasingly from space assets—and the ability to attack from that medium enhance the power of other surface forces on both land and sea. Given the vantage of the third dimension, one can see over all hills and better cope with an array of dispersed threats, distributed capabilities, and disparate data points.

Speed/Tempo

The speed with which airpower may be brought to bear is far superior than that which can be attained by surface forces. Land-based and sea-based movements are constrained by the laws of physics, geographic features, and weather to a greater degree than systems operating in the third dimension. Air and space vehicles can travel faster and are thus capable of acting or reacting more quickly to a crisis anywhere on the earth's surface. That speed can be modulated, and can range from a few hundred miles per hour to the speed of light in space where photonic particles themselves become a means of observation and designation, communications and weaponry combined. The advantage conferred by such a range of speed is not unique to airpower but it is relatively and uniformly more useful in the third dimension than on the earth's surface.

It is what speed conveys—responsiveness—that is essential to airpower. The timeliness with which one can know, assess, decide, react to, and affect events is greatly enhanced by the speed of airpower. Airpower assets are somewhat limited by weather and terrain but they are not limited to anywhere near the

degree which confounds surface forces most of the time. And, depending on the type of sensors being used from space, even weather may cause little or no difficulty. There are no valleys or river gorges, no mountains or deserts in the air, and one's ability to traverse such terrain faster is relatively unimpeded in the third dimension. Reaching nearly any point on the globe from any other point is possible in a matter of hours. Through aerial refueling, there is no spot on the earth's surface that cannot be reached within less than 20 hours,[49] many within half that time. To attempt to transport men, materiel, and munitions on the earth's surface takes days and weeks for the Navy, weeks and months for the Army.

The ability to modulate the speed of activity in—and coming from—the third dimension is essential to strategic effect. The tempo can be fast or slow, and it can be varied between extremes. The presence of airpower can be episodic, in the form of a sudden and massive offensive strike, satellite pictures of different kinds at a particular date and time, or a single munition delivered from afar by a missile. Or it can be persistent, in the form of UAVs or sustained airlift operations for resupply, or aerial-refueled AWACS and fighter coverage of a certain spot on the earth's surface. The modulation of different types of airpower and variability in the tempo of operations means that there is no recognizable pattern for enemy sensors to establish or to which the enemy can respond effectively. Modulating tempo promotes unpredictability and unpredictability promotes survival.

Range

Simple physical realities convey a distinct advantage to airpower. Approximately 30 percent of the earth's surface is land. Another 70 percent is water. But 100 percent of the earth's surface is covered by air and the air envelope of the atmosphere in turn surrounded by space. Air and space constitute the third dimension and that is the province of airpower. Aerial refueling capability means that airpower truly has global reach. *That is, there is no place over the surface of the earth where airpower cannot go and no point on the earth's surface which airpower cannot affect in one way or another.* Space systems in constant earth orbit have both a speed and a range far greater than atmospheric ones. They can travel at orbital velocities in excess of 18,000 miles per hour and circle the globe in 90 minutes or so. While air-breathing vehicles cannot do nearly as well in relative speed, they share global reach as an attribute. They can go farther, faster, and with greater strategic effect than surface forces can. This ability to "reach out and touch someone" anywhere, and do so at any time, is unique to airpower. And increased space capabilities will only improve our range and reach.

Range is a spatial relationship. It involves distance and reach. The responsiveness factor mentioned above has a spatial as well as a temporal dimension. Global reach achieved by the characteristic of range means that responsiveness occurs in space as well as time. Getting anywhere is as important as getting there anytime. *More specifically, getting precisely there, in time, is the key to affecting events elsewhere in the world.* Hence, the responsiveness of airpower flows from both speed and range. These characteristic attributes of airpower thus confer a strategically and tactically important operational capability on it—responsiveness. All hinge ultimately on awareness.

The Combination of Mass (Energy) and Maneuver

A major problem for most naval and land commanders has been the necessity to choose, at the right time and the right place, between the alternatives of mass and maneuver. One could either mass forces and fires at the decisive point of attack, or concentrate defensive forces and fires to repel them.

Alternatively, one could attempt to maneuver in such a way as to change the axis of advance, the avenue of attack and surprise the enemy who would be caught unawares. Either choice could lead to a great victory. Making the wrong choice at the wrong time, in the face of an adversary who had divined your intentions, could end in defeat.

Both mass and maneuver are principles of war. But in the past, one had to choose one over the other. If one maneuvered successfully, he was a hero who had, like Alexander, Napoléon, and others, split his forces and attacked the enemy from the flank or the rear to win a decisive victory. If one lost, it was because he had violated a principle of war and divided his own forces against a concentrated foe. On the other hand, if one concentrated his forces to wield a sledgehammer blow at a single point of the enemy's defense, broke through and routed his army, it was because he followed the principle of war and the Clausewitzian directive about massing forces for a decisive blow. If one lost, it was generally because his adversary had an inherently stronger position, massive fires in the defense, "the stronger form of war" according to Carl von Clausewitz, and repulsed the attack.

With airpower, one need not make the choice between mass and maneuver. One can maneuver to attack from any degree of the azimuth—360 degrees of choice and get to the point relatively unimpeded compared to a surface force commander. One can vary the axis of advance, the azimuth of attack, and the altitude from which it comes (high, medium, or low) so that the exact nature of the attack cannot be anticipated. And the attack may make simultaneous use of mass—in the form of aerial bombardment, be it from cannon fire, bombs, missiles, or standoff systems. This bombardment can be concentrated spatially, temporally, or functionally on a particular target. That is, it could seek to destroy an enemy's capital or central city, hit all air bases in the country at a single time, or take out all the major means of communication throughout the country—telephone, telegraph, microwave relay towers, radio and television transmission capability, postal service centers, satellite stations (both uplink and downlink), and so forth. If one has achieved air superiority, then all this is possible. The air component commander need not choose between mass and maneuver—he may employ both simultaneously, in a number of different ways.

As Albert Einstein showed in his theory of general relativity, mass and energy are related and, indeed, mass could be converted into energy. But we are now entering an era in which mass must be viewed simultaneously with energy. With lasers, we have light that has properties of both wave and particle. But photons are relatively massless, though energy-rich, in the form of light. Increasingly, photonic beams—as sensors, communications devices, navigational tools, and weapons—are the best examples of not only a multirole system, but a combination to the point of near simultaneity of target acquisition and destruction. This is certainly true in space and is increasingly the case even in the atmosphere. Hence, mass/energy/maneuver become fused as one. We are approaching an observation, orientation, decision, action (OODA) point—not an OODA loop.[50]

Versatility

One often hears the phrase "flexibility is the key to airpower" in the USAF—a truth uttered facetiously and in jest most of the time, referring to the constant changes in plans that affect military life. Flexibility—meaning bendable, adaptable—is not quite the same as "versatile"—also meaning adaptable but in the sense of being able to perform a variety of tasks, being capable of many uses. It is in versatility that airpower excels. Airpower is able to change from one task to another quickly and easily. Most of its platforms have multiple roles. They are capable of air-to-air combat or ground attack, in both defensive and offensive roles. Both pilots and planes are multifunctional and, in many cases, interchangeable on a

sortie-to-sortie basis. While other platforms and personnel in other services can perform offensive or defensive missions, they are not usually as capable of performing both strategic and tactical missions. The USAF uses its bombers and fighters in both roles interchangeably; the nature of the mission is defined less by the platform than by the target set.

There is yet another role that versatility plays in the application of airpower. The same platforms and personnel perform many of the same missions whether these be war fighting or MOOTW, peacetime or combat. And there are reserve and guard components to augment active duty forces. These components have much the same equipment and, in many cases, equal or superior skills. This gives versatility in the USAF a depth and breadth not found elsewhere in the American military. Army's roundout brigades are generally seen as inferior in combat capability, and the time required to mobilize naval assets in the fleet reserve is long. Such versatility is not to be found in other air forces either. US airmen find versatility and integration—of roles, missions, personnel, platforms—almost natural. One cannot plan or execute an air campaign without an ability to synthesize, to integrate disparate elements to achieve a desired outcome. The process of developing an air tasking order (ATO) and the concept and management of an objective wing are further examples of the ability to integrate, conceptually and operationally. Increasingly, space systems are dual use, serving both a commercial market and a military market—global positioning system (GPS), communications satellites, weather information satellites—are all examples. There are few cases in which army or navy assets are dual use with anywhere near the breadth of application and frequency of usage. *USAF versatility is a habit of mind, so ingrained in the application of airpower as to be a unique attribute of it.*

These attributes are not necessarily absolutes, however. In fact, they are relative and situational. It is in their comparative and cumulative aspects that these can be said to be unique attributes of airpower. Utilizing these attributes effectively allows the USAF to achieve air superiority, space superiority, precision employment, global mobility, and information dominance. These core competencies allow the USAF to achieve its mission: to control and exploit air and space in defense of the United States and its interests. The USAF thereby achieves global presence, global reach, and global power. While surface forces can be brought to bear anywhere, that can be accomplished only relatively slowly and with fairly long lead times. And, while the application of airpower is not instantaneous, continuing advances in technology reduce response times and make airpower's response far superior to surface force response. *Ab alto* is increasingly the preferred way—to communicate, navigate, gather information, transport people and materiel, observe, threaten, deter, defend, and apply power. And it is USAF that excels in these. It is the only "full-service" air force in the world. Its breadth of capabilities and the quantity of its assets are far greater than those of any other air force.[51]

The United States as an Aerospace Nation

This package of unique attributes, which airpower brings to the table, is fundamental and essential to the defense of the United States of America. The nation and airpower are joined in fundamental ways that are often overlooked or disregarded. The United States was a maritime Republic through most of its history, but it became, an aerospace nation—culturally, politically, geographically, technologically and economically—in the twentieth century.

Culturally, we represent a nation which proclaims itself a *novus ordo seclorum*—new order of the ages—on our currency. That was a rather brash and arrogant proclamation some 220 years ago for a fledgling state in the wilderness of a vast

continent. As a people, however, we have always been forward looking, had an abiding faith in engineering solutions to our problems, seen exploration as part of our national consciousness and outlook, and assumed progress synonymous with Americans—if not a God-given right. Airpower has always been seen as future-oriented, exploratory—"pushing the envelope"—and a sign of technological triumph and progress. Space is the final frontier, our high frontier, and our fascination with it continues.

Politically, airpower is the answer to a democracy's prayers. It offers a way to fight wars with far fewer casualties than if it had to be done the old fashioned way—on the ground. True, the test of going to war for America is the employment of ground combat forces. But unlike authoritarian and totalitarian regimes, which are happy to invest massive amounts of manpower in fighting wars, democracies prefer firepower over manpower. Others invest in quantity (numbers of troops) while we invest in quality (high technology weaponry). We husband our blood, not our treasure; they spend blood far more willingly than treasure. We invest in our people, providing the training and education to make them superior. And we trust them to defend us with the implements of national power rather than topple the existing government. Authoritarian and totalitarian regimes cannot afford that kind of investment; they have neither the level of requisite trust nor the political tradition of no military takeovers.

Geographically, we are committed to airpower because of our continental dimensions. Great distances placed a premium on the speed and range of transportation and communication. Railroads were a great boon to our development but when aerial capability emerged and became cost-effective, it became the preferred manner for travel, rapid transport, and communication. Blessed with good neighbors to the north and the south, we face no military threat from those neighbors. Blessed with two ocean moats to the east and the west, we were secure in the knowledge that we would have ample warning of armed attack by sea. Pearl Harbor shattered that illusion, however, and long-range bombers along with ICBMs have fundamentally altered it. The threat from abroad to the US, and the means of greatest surprise, is and always will be from the third dimension. Airpower has thus attained the stature of our premier deterrent force—a major defensive one. And since the end of WWII, airpower has been the primary means of power projection for strategic purposes.

Our geostrategic position means that if we seek to participate in the world, we must project our influence abroad. Not being territorially acquisitive in seeking new territory or peoples under our sovereignty—at least since achieving "Manifest Destiny" at the end of the last century—we have no need to occupy others' territory. We did so in earlier eras because that was how armies won wars. We fight our wars on other people's territories and, for this century at least, mostly to undo acts of aggression by others. Germany (twice), Italy, Japan, North Korea, Iraq—all were defeated eventually, but all held the initial advantage in surface maneuver to exploit. Airpower has been used in all those conflicts to counter that initial advantage asymmetrically, by projecting force and leveraging our advantage rather than fighting a bloody war of attrition on the adversary's turf and terms. It will be that way for the foreseeable future. Airpower gives us the capability to project force, to commit far less manpower in favor of high-technology assets to defeat our adversaries. Failing to use these advantages would be foolish and would make no sense to a concerned democratic electorate.

Technologically and economically, we were destined to make certain choices and investments because of our geopolitical circumstances. We made economic investments, commercial as well as military, in order to exploit the Wright brothers'

invention for our use. We took pride in playing a leading role in the development of airpower. Monument to a martyred president or not, the race to put a man on the moon was a national commitment in which we reveled. And despite the *Challenger* disaster and NASA's difficulties, despite the enormous costs of putting things in orbit and beyond, we are proceeding with the space station and deep space probes.

The third dimension represents the ultimate high ground. It is the essence of progress defined as onward and upward, the arena of greatest human and scientific challenge for us to conquer, the gateway to our solar system, galaxy, and universe, the envelope in which this "third rock from the sun" exists. Not to be wedded to the control and exploitation of air and space would be seen by many as to be almost un-American. To others, resentful of the huge costs involved in pushing the frontiers of our knowledge and capability ever outward from our planet, it seems a waste. But it is also an escape from our earthbound problems, and therein lies a reason that space and the third dimension will continue to fascinate and excite us in the future.

And what of the USAF in all of this? For better or for worse, despite a duplication of systems, multiple air forces, competing interests and platforms, budgetary battles and bureaucratic politics, *the USAF is the premier custodian of the third dimension and should remain such.* The nexus of expertise, however flawed it may be, lies there. The projection of airpower will be the manner in which we are most likely to first engage enemy forces as far from our shores as possible. And the best way to compensate for the enemy's initial advantage of surface maneuver is through the application of airpower. But the essential contribution is this: *Airpower can compensate for shortfalls in naval or land forces, tactically or strategically, to a greater degree and more quickly, than either of those can compensate for a shortfall in airpower.*[52]

The USAF is the service which best understands that reality. It is the sole service to have at its disposal the full panoply of airpower resources required to accomplish a variety of missions—deterrence, defense, offense—quickly, at great distance, in a variety of ways. It can accomplish a number of different missions anywhere at almost anytime. The USAF is the only service capable of establishing and maintaining air superiority. While airpower and air superiority cannot guarantee victory—as Korea and Vietnam reveal—they are a necessary, if not a sufficient, ingredient in America's wars. With air superiority, all is possible; without it, all is at risk.[53] And the Navy and the Army know it—more personally and professionally than does even the USAF. We are predominant in airpower capability and must remain so to protect United States interests. Not to utilize the one truly overwhelming capability we have vis-à-vis all potential adversaries in the world would be inexcusable.

Avoiding Extinction for the USAF and the US

Regardless of the shape of the world to come and the future in which we live, airpower should remain a critical dimension of national defense. To lose such a valuable commodity, by default or design, is unthinkable if we wish to preserve the security of our nation, our allies, and the kind of world in which we can survive and prosper. Though the possibilities for extinction of the USAF are many, they must be resisted and the USAF must adapt. The test of most successful military establishments of the past was their capacity for mutation and adaptation to a changing environment. The British adoption of the long bow, the adoption of the broadside in lieu of ramming in naval warfare, the wedding of the tank and the airplane in harnessing the internal combustion engine—all led to military success against great odds. Despite the risk and the array of threats to its very existence, the USAF has

proved itself over the years to be very adept at changing enough to survive, if not always prosper.

There are airmen of great skill and competence and intellect in the Army, Navy, and Marine Corps. But their skills and platforms are different, even if some of their munitions are the same, and their missions are fundamentally different. Their concern is tactical, not strategic. Their very definition of the situation is colored by the primacy of close air support for troops (for the Army and Marine Corps) or the importance of fleet defense (for the Navy). Their notions of air operations are different from those of Air Force officers in both scale and magnitude.

The airmen of other services lack an expansive appreciation—geographic, conceptual, and technological—of many assets that airpower encompasses. Space-based systems and satellite trajectories, tankers and aerial refueling orbits, the possibilities for strategic strikes deep within an enemy's homeland, the logistical complexity of large-scale airlift operations, and the planning tools for large-scale, and very complex air campaign planning with the array of air assets available, are largely beyond their ken, jointness not withstanding. What is missing in the view of airmen not in blue suits is the detailed knowledge, long practical experience, and expansive vision of airpower's possibilities—and the demonstrated capacity to implement it at a distance over a long period of time. Airmen in other services are certainly skilled and capable, but their skills exist in more limited fashion. And their parent services will more willingly sacrifice their airpower to the more central concerns of those services—the land and the sea.

More important still is the difference in intentions between airmen in the USAF and others. Airmen in the USAF know, or feel, even if they do not quite understand, that they have an opportunity to make a significant difference in the course of a war, the duration of the conflict, and the casualties that must be suffered in order for the conflict to end. The debate over whether or not airpower was decisive in the Gulf War is proof of this assertion. *Airmen in the USAF think that they can be decisive—and that attitude combined with their unquestioned aptitude makes all the difference.* The point is, without that conviction, no one will try to be strategically decisive in a short, quick, and less bloody air campaign. Therein lies the crux of the matter. The willingness to try and change the course of the war at hand—if not history itself—exists (or should) in airmen who wear blue suits as opposed to those who do not.

The Navy may be the initial force in contact in a crisis and its protection of sea lanes of communication is absolutely vital to the shipment of war materiel to the theater in which the war is fought. Ninety-five percent of the materiel shipped to the Gulf in Desert Shield/Desert Storm went by sea.[54] But sea blockades and wars at sea are no longer likely to succeed as they have in the past. The deployment and employment of 500,000 troops to a distant theater for large-scale ground combat may not be either a necessary or a desirable way to win a war in the twenty-first century—especially if it can be avoided. Large-scale, highly lethal ground forces are less and less useful than in the past because of their very high cost, the targets that such concentrations present to an enemy, and the bloody nature of an encounter with a foe who actually uses like weaponry (unlike Iraq). We need not fight a conventional war that way, and would not fight a war with nuclear, biological, or chemical (NBC) weaponry if we could possibly avoid it. Further, we know that we cannot kill our way to victory in revolutionary insurgencies. Why, therefore, should a land force attack be the preferred manner of engaging the enemy?

Air superiority—"command of the air," as Douhet called it—for the Air Force may seem to be not much different from a Mahanian notion of control of the sea for the Navy or battlefield dominance for the

Army. But it *is* different—it enables to a far greater degree the application and enhancement of joint and combined operations of nearly all types. With air superiority, all else is possible; without it, all else is at risk. Airpower can carry the war to an enemy faster, to a greater distance from our homeland, and with greater strategic impact, than can the bulk of naval forces (though they too can have strategic impact, particularly nuclear), or the Army, which is destined to slug it out on the ground the old-fashioned way.

If our goals were to seize and hold territory, to increase the population under our sovereign control, to expand the territorial holdings of the United States of America, then the Army would be the preferred instrument to accomplish these goals. But they are not our goals; we need not fight in this manner. We believe it is better to serve as an example for others to emulate than to conquer the world and make it conform to our preferences. Destroying key parts of an adversary's strategic calculus or his capability is better than destroying his capital. And any of these are preferable to fighting our way to it on the ground so we can then occupy the territory of a defeated enemy.

Appreciation of these fundamental realities lies at the heart of the need for a separate air force and its continued development. *As long as airpower is seen as an adjunct capability to the Army Corps commander or the Navy Fleet commander, it is not thought of or utilized as the CINC's primary strategic asset—and it will likely be misapplied.* Airpower's significant attributes are squandered when they are not wielded by airmen who understand that airpower's greatest contribution occurs when it is utilized offensively, with surprise, against strategic targets. While airpower can be of great value in a number of other roles—mobility, close air support, interdiction, fleet defense—those missions are decidedly secondary in nature compared to its primary focus and advantage—strategic attack.

Lessons of the Past and for the Future

We think we learn from the past, and that we profit from our mistakes and previous experience so we will not have to relearn painful lessons. Would that it were so! Americans have little sense of history. Hard lessons have a short half-life—about one-half of a generation. We often fail to learn what we should, or we forget what we think we have mastered. The following quotation is interesting in this regard.

What are the chief lessons with the strategic use of airpower in the last war?

> 1) One lesson is that the time we were given to make our preparations was an absolutely essential factor in our final success. . . . It is unthinkable that we should ever again be granted such grace.
>
> 2) Airpower in this war developed a strategy and tactic of its own, peculiar to the third dimension.
>
> 3) The first and absolute requirement of strategic airpower in this war was the control of the air in order to carry out sustained operations without prohibitive losses.
>
> 4) We profited from the mistakes of our enemies. To rely on the probability of similar mistakes by our unknown enemies of the future would be folly. The circumstances of timing, peculiar to the last war, and which worked to our advantage, will not be repeated. This must not be forgotten.
>
> 5) Strategic airpower could not have won this war alone, without the surface forces. . . . Airpower, however, was the spark to success. . . . Another war, however distant in the future, would probably be decided by some form of airpower before the major surface forces were able to make contact with the enemy in major battles. That is the supreme military lesson of our period in history.[55]

That is an accurate assessment of the US performance in the Gulf War, and it is sound advice for the future. It is a set of insights we would do well to heed. But it was not written about the Gulf War. It was written *45 years earlier* by Gen Carl ("Tooey") Spaatz as his assessment of WWII! The article, "Strategic Air Power: Fulfillment of a Concept," appeared in the April 1946

issue of *Foreign Affairs*. Somewhere between WWII and the Gulf War, we either failed to learn or conveniently forgot these lessons.

Fifty years hence, one might well repeat the quote above and everywhere the word "air" appears, substitute the word "space" and have it make eminently good sense. Indeed, it might be so obvious as to be overlooked. It is *toward* space that we are headed because it is *from* space where we are relatively advantaged. It is *in* space that we can have even greater leverage of our technological advantage, best offset our concern for casualties, accomplish our urge to be responsive, and achieve our need to project force against adversaries as far from our homeland as possible. And it will be the fusion of air and space assets that offers us the means to do so. Airpower means space power, as the Gulf War began to reveal. And none of the services intend to fight a war without increasingly relying on space-based assets.

In the future, the failure to have or appropriately apply independent airpower to a major military engagement would be largely indefensible. Regardless of how adept an Army victory might be on the ground, that victory will not likely occur without casualties—significant ones without more airpower than the Army has. And without a continuing investment in space systems, our technological lead will diminish, both relatively and absolutely. Imagine the congressional hearing held to determine the reasons behind the huge number of American casualties sustained in barely winning a future war by slugging it out on the ground. How would we answer the congressional questions that would be asked?

- General, in your opinion, why was it necessary for the United States to suffer more casualties than in either Korea or Vietnam in this war? Could that have been avoided?
- Why didn't we fight this war they way we fought the one in the Gulf years ago—with a longer air campaign and a short ground war (if we needed one at all)?
- Was occupying the enemy's capital and most of his country really necessary?
- Couldn't we have succeeded by punishing them severely and destroying their military capability, if not their will to resist?
- General, when will we stop paying twice for every war we fight? We end up paying once to destroy the enemy and again to pay for his reconstruction!
- Why shouldn't we let the neighborhood fight over the carcass? As long as the enemy is no longer a threat and we have demonstrated our airpower capability, the odds of somebody else pushing the limits are not very good in the short run, are they?

Decisive victory need not—and should not—be achieved only by ground combat. Nor does it have to mean occupying the enemy's territory.

Airmen *do not* understand that definition (ground combat) of decisive. They seek another vision. Theirs is one where deep strategic strikes make ground war either unnecessary or anticlimactic. In an era in which we, who are not the aggressor, seek to have and retain moral ascendancy, can reach anywhere on the planet via air and space, can impede if not prevent the accomplishment of an adversary's war aims and dilute seriously if not kill the strength of his will to resist, why would we not first use an air campaign to try to thwart an enemy if not utterly defeat him? Why would we send large numbers of US troops in harm's way if smaller numbers of pilots, planes, laser-guided bombs, and missiles could accomplish the same thing? While airpower may not be sufficient to win the next war, no one wants to fight without it. And the Army and the Navy will admit such, albeit quietly and reluctantly. *Massive airpower is absolutely necessary to how the American military should fight and win its*

nation's wars. To think otherwise is an act of self-delusion.

Successful Evolution: The USAF in the Twenty-First Century

The survival and continued prosperity of the United States of America are supported by and maintained by the nation's investment in air and space, and by the superior ability to exercise airpower—control and exploitation of the third dimension—in support of the nation's interests. The one sure path to extinction for both the USAF and, ultimately, the nation—would be to disinvest in airpower and the core competencies that it provides when utilized as an independent armed service. We simply cannot allow that to happen. If the USAF does become extinct, its passing will negatively affect not only the US but also the rest of the world. Conflicts that could have been avoided, deterred, successfully defended against, or eliminated may now be more likely to erupt.

The collection of space-based sensor information, the delivery of missiles or bombs on target, or the achievement of air superiority are not ends in themselves; they are instrumental goals. They are not merely good, but good for something else—for what they in turn can offer. That something else is a more secure environment in which the United States and its allies may survive and prosper. Anything else, if not irrelevant, is at least less so. And while there is much the USAF *could* do, there is less that it *should do* in support of national security strategy and national military strategy. For example, boring holes in the sky in Deny Flight for an ineffectual political purpose and minuscule military impact may well be a waste of resources which we cannot afford. Scarce resources are valuable *because* they are scarce. They must be husbanded. They should be expended only with great care, for good purpose, and with reasonable chance of success. We may not always meet that test successfully.

The USAF that we seek to preserve and to make prosper in service to the nation should be relatively small, highly professional, well trained, confident, well equipped, and organized to carry out a variety of roles and missions quickly and effectively with the least amount of extraneous duplication. It should be seen as the custodian of the third dimension—both air and space. It should possess capabilities across the spectrum of conflict, from OOTW missions to nuclear war. Its primary emphasis should be on surveillance and force projection, on knowing what is going on in the world and letting others know that we know. Information dominance—controlling the content and flow of information when necessary—should become increasingly important. And the responsiveness of airpower should be enhanced. Enhanced, that is, by our investment in global awareness, which increasingly flows from our presence in space.

Any mission that can be performed better or more quickly by others without unnecessary duplication, any platform that does not need to be in the USAF inventory, any role which does not accentuate the attributes of airpower and enhance its core competencies—these should be cheerfully and readily relinquished. Meanwhile, we must seek to enhance the basic attributes of airpower perspective, speed/tempo, range, mass/energy, maneuver, and versatility—within tight budgetary constraints and the need to balance research and development with operations and maintenance for a ready force. If these can be achieved, then the USAF will be preserved. If they cannot, it is doubtful that USAF will survive very far into the twenty-first century.

An Aerospace World

An aerospace world would be one in which the investment in, exploitation of, and benefits from, air and space would continue to grow both absolutely and relatively. Whether the investments were commercial or military, public or private,

improvement in knowledge, transportation, communication, navigation, and surveillance in air and space will continue—to grow if only because of the continuing effort to shrink time and distance for those who inhabit the earth and the utility of the third dimension. Perspective and versatility will continue to have high value, and will continue to confer even greater capabilities on the air component commander, who seeks to employ mass and maneuver simultaneously and to leverage asymmetrical strengths against miscreants on the earth's surface as well as in air and space. Increasingly, we will become a spacefaring nation. Missiles and missile defense, increased bandwidth for communications, directed energy weaponry, UAVs, transatmospheric vehicles (TAV), and increased "infospheric" capabilities—all will become increasingly important.

Lack of these items and characteristics would indicate disinvestment in an aerospace world. Such a nonaerospace world would be neither as economically prosperous, as technologically advanced, as interdependent politically, or as militarily differentiated as an aerospace world. The margins of power, relative and situational though they are, would be narrower in almost every way—economic, technological, political, and military. The dominant role played by the US, in large part dependent on airpower, would be at risk. A nonaerospace world would favor those with a large quantity of soldiers rather than those with a high quality of airmen.

Airpower is inescapably linked to the growth and vitality of the nation. We have progressed from land-based notions of Manifest Destiny and the simultaneous expression of America as a seafaring nation. We have now disinvested, relatively, in both of these concepts and their requisite competencies as new technologies have emerged. We have no desire for territorial aggrandizement and we have a minuscule merchant marine. We allow others to transport goods by sea while we are engaged in other activities, where our comparative advantage lies. Americans interact with the world via air and space and, increasingly, through the flow of ideas and products, which are exported abroad both physically and electronically. Promoting, preserving, and protecting the interchange of people, products, services, money, and ideas is central to our national security our continued growth and development as a nation. And airpower—air and space assets and capabilities—is central to our ability to survive and prosper in the next century. It is increasingly through air and space that we travel, transport, communicate, observe, orient, decide, and act in both civilian and military activities.

The Bottom Line

It is not the existence of any one of these concepts that makes airpower unique or the USAF necessary; it is, rather, the understanding of their integration and creative application which leads to an awareness that extinction of the USAF would likely hasten the extinction of the US. Airpower, as exemplified by the USAF and the air and space capabilities at its disposal, is, and of rights ought to be, an essential aspect of US security for the foreseeable future. It is best employed as an independent, full-service capability wherein training, doctrine, organization, equipment, technology, understanding, and attitude are focused on its unique combination of competencies—and on the roles and missions they can perform quickly, at great distance, with less loss of life, with improved information flows, in versatile and unpredictable ways. As our capabilities increase, airpower will be increasingly defined and refined as spacepower.

Could the US long continue to survive, prosper, and protect its territory, citizens, assets, values, activities, and roles in the world without an independent air arm? The answer is emphatically, "no!" Why, then, should we disinvest in our capability to achieve our national objectives by allowing the USAF to become extinct? That it *could* happen does not mean that it *should*

happen. And because the consequences of such an occurrence are so great, we should do everything in our power to prevent it. Like Blaise Pascal's wager on the existence of God, the consequences—should we be wrong in wagering that we could make it without the USAF—are so great as to vitiate the attempt. The advantages airpower confers, as wielded by the USAF, are so great that we dare not do without them.

Perhaps most important is the need to accept the truth, as captured in the insight of retired Air Vice-Marshal Tony Mason: "By placing airpower in the evolutionary process of warfare, as a whole, unnecessary claims of superiority and unfounded fears of subordination may be abandoned along with the growing pains of infancy and adolesence."[56] It is no longer necessary to defend a *revolution* called airpower; it is time to nurture airpower's *evolution* through creative adaptation of air and space capabilities. In so doing, we will avoid extinction for both the USAF and the nation.

Airpower—our capability in the third dimension (air and space)—is unique, valuable, and versatile. But while airpower can do much, it can't do everything. It is necessary but it may not always be sufficient. It can be, but may not always be, decisive. In any case, airpower is a critical part of our nation's ability to survive and prosper. As such, it must be wielded wisely by those who understand both its capabilities and its limitations. Its value to the nation is not merely significant, it is vital—quite literally "necessary to life." To squander it—whether through mismanagement, ignorance, or petty politics—is an outcome which in the long run is unacceptable. Not having the USAF would be far more costly than maintaining it—an admittedly expensive, but necessary and valuable, set of capabilities. Extinction of the USAF risks extinction of the nation. We would do well to avoid both.

Notes

A note on background and bias is appropriate. The author is a civilian academic who came to an appreciation of airpower rather late—and through observation and study rather than application. His own military service was limited to a brief stint in the US Army (Inf) on active duty and a number of years in the reserves. He has been informed through the study of twentieth century military history by reading works of others on airpower and through discussion with students, speakers, and faculty at the Air War College and elsewhere over the past seven years. His knowledge is vicarious. He is not a pilot, has zero hours in the cockpit, and has not directly witnessed airpower in combat. What he has to say, therefore, may be taken with the proverbial "grain of salt."

The author is indebted to numerous colleagues, and to current and former students, at the Air War College for helping him to refine his views on the unique characteristics of airpower. In particular, I would like to thank Col John R. Boyd, USAF, Retired; Mr Carl H. Builder of RAND; and Maj Gen Charles D. Link, USAF. I would also like to thank Dr Alexander Cochran, Col Jae Engelbrecht, Jr., USAF, Dr Irene Pearson-Morrow, Col Richard Szafranski, USAF, and Dr James H. Toner, all of the Air War College, for their insights and commentary on earlier drafts of this manuscript.

1. Maj Gen Charles D. Link, briefing entitled, "AIRPOWER: An Airman's Perspective," given at the Air War College, 7 March 1996. Used with permission.

2. Carl H. Builder, *The Icarus Syndrome: The Role of Air Power Theory in the Evolution and Fate of the US Air Force* (New Brunswick, N.J.: Transaction Publishers, 1994), 7.

3. Harold R. Winton, "Partnership and Tension: The Army and the Air Force between Vietnam and Desert Shield," *Parameters*, Spring 1996, 115. The information cited is taken from a thesis by Maj James M. Ford, "Air Force Culture and Conventional Strategic Airpower" (Maxwell AFB, Ala.: School of Advanced Airpower Studies, 1992), 60.

4. In addition to the Winton article cited above and Builder's book cited in note 2, see also Gen Robert D. Russ, "The Air Force, the Army and the Battlefield of the 1990s," *Defense 88*, August 1988, 12–17.

5. See Col Edward C. Mann III, *Thunder and Lightning: Desert Storm and the Airpower Debates* (Maxwell AFB, Ala.: Air University Press, April 1995).

6. Col Richard T. Reynolds, *Heart of the Storm: The Genesis of the Air Campaign against Iraq* (Maxwell AFB, Ala.: Air University Press, January 1995).

7. The casualty rate for 20-30-year-old males in the US during the Gulf War was 104 per 100,000. The casualty rate for the same age group deployed in the Gulf War was 69 per 100,000. "*Harper*'s Index," *Harper's Magazine*, May 1991, 17.

8. On digitizing the battlefield of the future, see Gordon R. Sullivan and James M. Dubik, "War in the Information Age," *Military Review*, April 1994, 46–61.

9. The debate over controlling battlespace and defining the deep battle is a matter of who controls fires in the area between the forward edge of the battle area (FEBA) and the fire support coordination line (FSCL) and how far does that space extend. If the Army Corps

Commander controls joint fires in this area and it extends from only 30 km, it is one thing. If he controls these out to 70 km, it is something else. If he controls them to a distance of an ATACM, we have redefined strategy and given the ground component commander a role he does not now have. In all these cases, aerial bombardment is conditional upon the approval of the ground component commander's scheme of maneuver and the scheduling of his fire support requirements. One can gain a sense of the importance of such seemingly parochial doctrinal issues in reference to the Gulf War. The FSCL was moved back and forth in the final hours of the Gulf War in such a way that the USAF could not strike targets it could easily have hit because they were reserved for Army fires which were insufficient at that time. See Michael R. Gordon and Gen Bernard E. Trainor, *The General's War: The Inside Story of the Conflict in the Gulf* (Boston: Little, Brown & Co., 1995), 411–13.

10. The *Air Force Issues Book* is the text of the Joint Posture Hearing Statement presented to Congress by the Secretary of the Air Force by Dr Sheila E. Widnall and Chief of Staff Gen Ronald R. Fogleman at the FY 96 Posture Hearings. *1995 Air Force Issues Book* (Washington, D.C.: Department of the Air Force, n.d.), 15.

11. The second US Army Space "think tank" meeting was held in Washington, D.C., on 25–26 January. Among the items presented at the meeting were recommendations that the Army pursue the exploitation of other people's sensors and platforms, long-range and long-endurance organic UAVs with multiple missions, a less vulnerable or better protected GPS, improved counterbattery operations and a set of transatmospheric vehicles (TAVs) called Hopper, Skipper and Jumper. These indicate not only the intent but a search for capabilities to allow the US Army to undertake current US Air Force roles and missions.

12. Gordon and Trainor, 58.

13. See the discussion in John Keegan, *A History of Warfare* (New York: Alfred A. Knopf, Inc., 1993), 67–70.

14. *1995 Air Force Issues Book*, 36.

15. See Adm William A. Owens, *High Seas: The Naval Passage to an Uncharted World* (Annapolis, Md.: Naval Institute Press, 1995).

16. See Martin C. Libicki and James A. Hazlett, "Do We Need An Information Corps?" *Joint Force Quarterly*, Autumn 1993, 88–97.

17. This is explored in some detail in a paper by Col Richard Szafranski, Air War College, and Martin C. Libicki, National War College, ". . . Or Go Down in Flame," forthcoming.

18. See the section entitled "The Mexican Financial Crisis and the Fall of the Dollar," in National Defense University Institute for National Strategic Studies, *Strategic Assessment 1996: Instruments of US Power* (Washington, D.C.: National Defense University Press, 1996), 58.

19. The case for this and alternative scenarios are presented in Michael O'Hanlon, *Defense Planning for the Late 1990s: Beyond the Desert Storm Framework* (Washington, D.C.: Brookings Institution, 1995).

20. Builder, 8.

21. A briefing, given by Eliot Cohen, director of the Strategic Studies Program at the Paul H. Nitze School of Advanced International Studies at The Johns Hopkins University and the head of the USAF Gulf War Airpower Survey, given on 7 March 1996, to the National Institute for Public Policy and since around Washington argues this point about increasing costs of systems with detailed charts for both bombers and fighters.

22. The validity of an isolationist foreign policy for the United States is cogently argued in Eric S. Nordlinger, *Isolationism Reconfigured: American Foreign Policy for a New Century* (Princeton, N.J.: Princeton University Press, 1995).

23. *1995 Air Force Issues Book*, 3, 4, 33.

24. See the discussion of "Weapons of Mass Destruction" in the Institute for National Strategic Studies, *Strategic Assessment 1995: US Security Challenges in Transition* (Washington, D.C.: National Defense University, 1995), 115–26.

25. For a review of Jean Raspail's *The Camp of the Saints*, first published in France in 1973, and an article elaborating on its themes, see Matthew Connelly and Paul Kennedy, "Must It Be the Rest against the West?" The *Atlantic Monthly*, December 1994, 61–63, 66, 68–70, 72, 76, 79, 82, 84. The general idea is the barbarian have-nots invade western Europe and "trash" western civilization by their very numbers. The civilized peoples of the world acquiesce in their own demise rather than compromise their principles and tolerance.

26. Maj Gen Charles D. Link, briefing entitled, "AIRPOWER: An Airman's Perspective," given at the Air War College, 7 March 1996. Used with permission.

27. FORSCOM G-3 Briefing on Roving Sands *95* prepared by Lt Col Bill Bayer, n. d.

28. See Reynolds, *Heart of the Storm.*

29. *1995 Air Force Issues Book*, 3–4.

30. This is not a private USAF matter reflecting internal disagreements but has become one of public discussion in both political and academic circles. Comments about the Commission on Roles and Missions debates, the release or suppression of the Gulf War Airpower Survey, USAF studies and public relations problems with such issues as the *Enola Gay* exhibit at the Smithsonian have been fairly common over the last five years. For some examples, see a letter by Alfred M. Beck to the *Journal of American History*, December 1995, 1336–37 and the comments in note 4, page 520 of Gordon and Trainor.

31. See Fred Polak, *The Image of the Future*, translated and abridged by Elise Boulding (San Francisco, Calif.: Jossey-Bass, Inc., 1973).

32. *1995 Air Force Issues Book*, 35.

33. Speech by Maj Gen Charles Roadman, commander of the USAF Medical Operations Agency,

given at Maxwell, AFB, Ala., on 7 February 1996. Cited in the *Maxwell-Gunter Dispatch*, 16 February 1996, 4.

34. Statistics compiled from data in *Air Force Magazine*, May 1995, 37, 53.

35. *1995 Air Force Issues Book*, 32.

36. Col John R. Boyd, USAF, Retired, phone conversation, 20 November 1995.

37. Norman R. Augustine, *Augustine's Laws* (New York: Viking Books, 1986), 111. Augustine's Law XVI states "In the year 2054, the entire defense budget will purchase just one aircraft. This aircraft will have to be shared by the Air Force and the Navy 3½ days per week except for leap year, when it will be made available to the Marines for the extra day."

38. See the final report of the USAF CSAF Study, *SPACECAST 2020* (Maxwell AFB, Ala.: Air University Press, 1994). This report was an effort by the USAF to examine its relation to space and to determine the emerging technologies in which it should invest.

39. The popularity of Capt Scott O'Grady's recent book with Jeff Coplon, *Return with Honor* (New York: Doubleday & Co., 1995)—is just one indication of the media events surrounding his shoot down, eventual rescue, and his "hero's" welcome upon his return to the US.

40. See Builder regarding the evolution of USAF doctrine.

41. The House vote authorizing the use of force for the Gulf War resolution was 250 to 183. The Senate vote was much closer: 52 to 47. A change of three votes would have denied legal authority to act as we did. Gordon and Trainor, 205.

42. A draft study—not yet released—by Eric Larson of RAND provides a very interesting analysis of the public's sensitivity to casualties.

43. A senior USAF general officer speaking under the promise of nonattribution in a speech to the Air War College, May 1991.

44. A senior Marine general officer speaking under the promise of nonattribution in a speech to the Air War College, May 1995.

45. Alvin and Heidi Toffler, *War and Anti-War, Survival at the Dawn of the 21st Century* (Boston: Little, Brown & Co., 1993), 10.

46. For some dated but cogent and still relevant comments on the military mind, see Bernard Brodie, *War and Politics*, 479–96. See also remarks made by Gen Robert Russ, head of the USAF Tactical Air Command (TAC) cited in Mann, 164.

47. A letter circulating in the USAF hierarchy from Carl Builder of Rand entitled "Ten Messages for the Chief" addresses many of the problems and gives sound advice for coping with them.

48. The desire to see the other side of the hill is a traditional statement regarding intelligence. The array of sources which the USAF has at its disposal for looking at the other side of all the hills—by satellite, high flying reconnaissance assets, UAVs, tactical aircraft—and in a variety of ways—photographic, infrared, radar, communications intercepts, and so forth—is unsurpassed and global.

49. *1995 Air Force Issues Book*, 5.

50. Col John R. Boyd, USAF, Retired, is the father of the "OODA Loop" concept, which has permeated Army, Marine Corps, Air Force, and even business thinking along with its related notion of cycle time. For information on the OODA Loop, its evolution and its impact on others, see, among other sources referring to it, James G. Burton, *The Pentagon Wars: Reformers Challenge the Old Guard* (Annapolis, Md.: Naval Institute Press, 1993), 51–58; Oliver Morton, "A Survey of Defense Technology," *The Economist*, 10 June 1995, 5–6; Joseph J. Romm, *Lean and Clean Management: How to Boost Profits and Productivity by Reducing Pollution* (New York: Kodansha, 1994), 107–11, 122–27; and James P. Stevenson, *The Pentagon Paradox: The Development of the F-18 Hornet* (Annapolis, Md.: Naval Institute Press, 1993), 45. Boyd, who retired in 1975, has never published anything outside the USAF but he and his work have been cited in over 20 books and more than 100 articles in publications ranging from *Forbes* and *Fortune* to *US News and World Report* and *Time*, from the *Harvard Business Review* to *Joint Force Quarterly*. After designing the F-15 and F-16 fighters in the 1960s and 1970s, he and his "radical" ideas were, until this decade, rather studiously avoided by the USAF. He had far greater impact on the US Marine Corps and the US Army than the USAF in terms of doctrinal thinking.

51. As an example of the scale and dominance of a full service air force, the US inventory of aerial refueling tankers (KC-135 and KC-10) numbers 583. (*Air Force Magazine*, May 1995, 37, 51.) The Russians have perhaps 50, the British 36, the Saudis 16, Iran and Israel 14 each, France 11. We do not know about Libya and China. No other country has more than single digit numbers of tankers. (Data from *Military Technology* 19, no. 1 [January 1995]). Thus, the USAF has roughly three times the number of tankers in the rest of the world combined.

52. Maj Gen Charles D. Link, briefing entitled, "AIRPOWER: An Airman's Perspective," given at the Air War College, 7 March 1996. Used with permission.

53. Maj Gen Charles D. Link, "The Role of the USAF in the Employment of Air Power," in Richard Shultz and Robert Pfaltzgraff, *The Future of Airpower in the Aftermath of the Gulf War* (Maxwell AFB, Ala.: Air University Press, July 1992), 86.

54. Gordon and Trainor, 58.

55. Gen Carl ("Tooey") Spaatz, "Airpower: The Fulfillment of a Concept," *Foreign Affairs*, April 1946, 394–96.

56. Air Vice-Marshal Tony Mason, *Airpower: A Centennial Appraisal* (Washington, D.C.: Brassey's, 1994), 278.

". . . Or Go Down in Flame?" An Airpower Manifesto for the Twenty-First Century

Col Richard Szafranski, USAF, Retired, and Dr Martin Libicki

To lead is to choose. Choosing commits one's group to courses of action and to consequences. In 1995 the leaders of the United States Air Force asserted long-range planning in the Air Force was "broken," and they would fix it. Doing so requires vision, a sense of the evolving environment and a process for linking visions to strategies and tasks. Bureaucracy without vision mistakes activity for progress. Vision without the wherewithal for change is called dreaming.

Planning today matters because the Air Force, in our view, is poised between two courses—one is to "live in fame," the other to "go down in flame," as the Air Force song goes. Bad choices forebode institutional irrelevance or, worse, disintegration and defeat. Some may find contemplating a future with no Air Force a distraction, waste of time, or logical impossibility, but it is none of those.

Why Change?

By now, it is hardly news that the Department of Defense must come to grips with two fundamental discontinuities.

The first one involves the "why" of military power in the wake of the Berlin Wall's fall. No one knows whether history—the domination of world politics by great power struggles—has ended, simply taken a breather, or is in the process of transformation. Absent knowing, it ill behooves the United States and its armed forces to await history's return recumbent. As nettlesome as today's challenges may be, it is difficult to foresee any circumstances under which the reemergence of a hostile great power would enhance the national security of the United States. In the cold war, the Air Force prescribed bombers and ballistic missiles to help deter any feverish confrontation from getting too hot. Today's environment mandates rethinking the capabilities required to deter tomorrow's great powers from overly hostile posturing.

The second discontinuity involves the "how" of military power in the enveloping onrush of information technology. Simply put, *being digital*, to use Nicholas Negroponte's meaning of the new ontology, means the high ground is no longer aerospace, in and of itself, but cyberspace. Understood in its broadest sense, cyberspace is the great confluence of all the various bits and information streams which, together, generates the strategic topsight prerequisite for victory.

By history, predilection, and structure, topsight is the natural (but not automatic) domain of the Air Force. But prior to staking its claim to tomorrow's high ground, the Air Force needs to redefine itself as an infospheric institution rather than an atmospheric one. This is the soul of our manifesto. It is toward envisioning and guiding this transformation that our essay turns.

Understanding the implications of this proposed transformation for the Air Force requires starting from first principles. The mission of the Air Force is not merely what we do (tending toward air and space operations) but what we contribute (determining how to operate for strategic effect). While knowing how to transport mass or energy to targets—plinking tanks or flattening cities—has its time and place, it is but a subset of knowing how to get and use knowledge to confound or terminate the production, distribution, and (increasingly) control of all sources of opposing military strength. Technology permits ends—strategic superiority—to be achieved through many means: space-based, atmospheric, ground-based,

and maritime systems, both manned and unmanned. If a separate Air Force exists for strategic purpose, then information, rather than any one attack method, becomes central; hence, a rationale for the Air Force to drop its atmospheric orientation in favor of an infospheric one. Just as the Air Force was born to exploit the technology of flight, it must also evolve to reflect subsequent technologies of equal strategic heft. Our notions of the "high ground" must change as airmen accept the *coup d'oeil* as the peer to and enabling means for the *coup de grâce*.

The Air Force was founded on the principle that mastery of the new technology would allow a nation to leap over World War I's bloody stalemate and strike a strategic blow to the enemy's war-fighting machine. Air—the atmosphere—became the high ground. Taking it made victory everywhere else only a matter of time and will. It so happened that in the first interwar period (we may presently be in another), this technology was reified in manned aircraft, since only the human body had the sensors and computing power needed for airpower's chores. But technology is protean by its very nature and, as Operation Desert Storm was the first to demonstrate, the information realm is becoming tomorrow's high ground. Simply put, if you can see the enemy and the enemy cannot see you, then only modest applications of precisely aimed, correctly timed force suffice to command the battlespace. This is the ground which, we argue, the Air Force must seek to command.

Before examining the transition from atmospheric to infospheric force, fairness requires noting two alternative visions: the "constabulary" Air Force and one based on information warfare. Both capabilities—one based on peace operations and the other on targeting enemy information systems—are valid new tasks. Neither, however, provides a reasonable heart and soul for tomorrow's Air Force.

The constabulary Air Force, so brilliantly elucidated by Carl Builder, is nevertheless highly problematic. Very little "force" is left; food "bombs" on friends may be necessary but hardly suffice for strategic leverage against enemies. Such a force provides little insurance against the reemergence of serious great power rivalry. A weakened constabulary Air Force might even beckon such fools forward. Once alienated from its core focus, the Air Constables may not be able to recover if history returns.

Adopting the trendy profundity and modernity of "information warfare" as a primary mission is often (wrongly) read into the Air Force statement on information warfare, *Cornerstones*. Yet, warfare is distinguished from brawling not through its inscrutability or novelty but through its discipline and causality in the grinding application of power. Strategic information operations—the unleashing of viruses, worms, Trojan horses, and others of that seemingly magical (or perhaps mythical) menagerie described by Doug Waller for the world in *Time*—tend to reach their highest utility against enemy national infrastructures just prior to conflict. This fact alone should suggest wariness in putting any military in charge (and even more so for strategic information defense). At the operational level, no one really knows how much good—let alone harm—information attacks can do. Such operations are opportunistic, and thus antithetical to an *ethos* built on strategy-to-task generation. Foes with no infrastructure to disrupt leave such a redefined Air Force with nothing to do.

The Air Force as a Joint Force

How does our vision of seizing and controlling the high ground harmonize with the vision of the other services and the Joint Staff? The latter's *Joint Vision 2010* was designed to scan the strategic horizon, promote joint force, and thereby inform the "visions" of the separate services. It seeks virtue in unchangeable aspects of fighting. Will there be precision strike in the future? Yes. Will one side strive to have greater awareness than the other? Of course. Would it be efficacious if joint forces could envision and engineer the dominating maneuver?

Absolutely. Does focused logistics facilitate resupply? Unremarkably so. Alexander, the Great Khan, and Napoléon would applaud these attributes, finding them familiar.

What is left unsaid, though, matters more. Neither legislation nor downsizing makes jointness necessary as much as does the tendency of every service's target acquisition and prosecution systems to overlap. The battlespace is as indivisible as the cyberspace. It can no longer be divided into neat domains and parceled out to each service to fight its own war—the Navy in the littoral, the Army in the fields, and the Air Force high and deep. They just keep getting in each other's way.

A future air force cannot help but envision the totality of the joint and integrated armed forces. At the heart of this joint vision is likely to be a vast, interconnected, interoperable, and ultimately integrated metasystem (a "system of systems" or, farther on, an "organism of organisms"), to which all services contribute and from which they all draw. The metasystem is not the elusive silver bullet or golden BB but the convergent architecture of capabilities nurtured by deliberate planning. It will not be a single machine or even a single network, but its users will not care—as far as they are concerned it will be the common instrument with which all carry to war. Feeding it will be rules of engagement, commanders' intents, strategic intelligence, bitstreams from space, continuous logistics reports, status of forces, weather observations, sensors from everywhere, operator inputs, and even the output of global news networks. It will supply the raw material of nearly total situational awareness, from global overlay to designated targets. If the metasystem is to do serious work, it has to be planned from the start as an integrated system, even though initially composed of legacy devices and codes. It will not do to glue today's increasingly inadequate systems at their edges and be done with it. Such a conceit grossly understates both the requirements for real-time battlespace control and the degree to which technology can empower greater vision. In the end, someone must be in charge of building and maintaining it for whoever is asked to command it. Who better, we argue, than the Air Force? It was Air Force's *SPACECAST 2020* that introduced the notion of "Global View" and the institutional pronouncement of a new and virtual form of engagement in "Global Presence" that followed in hot pursuit.

The Air Force need not populate the entire metasystem—an organic construction of various pieces being built, tested, used, refined, reused, swapped out, and retired in their turn. What the Air Force must do, though, is envision the metasystem's architecture and all that it implies: requirements, doctrine, tests, protocols, agents, and objects. Once that is well understood, the metasystem will grow naturally—with the Air Force vision of topsight as the ghost in the machine. Guardianship over the metasystem, we argue, is the aspect of controlling and exploiting the high ground that differentiates a next-generation infospheric air force from an air force slowly yet inexorably being petrified in the amber of slightly faster, slightly stealthier atmospheric operations. An infospheric air force possesses capabilities which lock out all would-be competitors and make their air and surface forces noncompetitive with ours.

An "armed" force with information but no means to convert it into striking power, needless to add, is pointless. The best "OO" does not obviate the need for "DA." The metasystem informs but does not replace command; operators are still in charge, and the air force will get its fair share at the top. As for weapons, an infospheric air force must nevertheless be armed. For tomorrow's evanescent battlefield, faster means of energy delivery may be needed, lest targets disappear before energetic force can engage them. Tomorrow's air force can and ought to listen to its visionary operators and scientists and engineers: seek real-time engagement weapons ranging from lasers to neutral particle beams and high-powered, focused microwaves. Indeed, the need for

fast sensor-to-shooter coupling, consistent with reifying information, calls for the Air Force to strengthen its command over strategic (not just nuclear) weapons, particularly those closely linked with the metasystem itself.

Tomorrow's Missions

If jointness provides one leg for tomorrow's air force, the emerging mission profile of the US armed forces provides the other. The United States took away four enduring missions from the cold war: strategic deterrence, conventional overseas intervention, guarding the lines of communication, and dissuasion (e.g., air strikes against Libya). Students of the "New World Chaos" often add peace operations and support for domestic authorities, but neither may last (one political party does not like performing them, while the other party does not like resourcing them) or carry much relevance for the Air Force.

Technology and today's need to deter and defer major power rivalry suggest three new missions will emerge over the next quarter century: extended information dominance, global transparency, and strategic defense.

Technology both enables and requires that the information dominance sought by the United States be extended to its friends. Apart from "stealth" (rare, expensive, and always incomplete), tomorrow's battlespace will be far more transparent than today's—to both sides. Why? Everything creates a signature of some kind—be it sound, odor, contrail, pressure, movement, or twitches in the geomagnetic environment. Every new bit illuminates the battlespace—whether discovering the tank in the weeds or the aircraft in the clouds—and the number of bits per buck has been doubling every 20 months, a trend with at least a decade of momentum remaining. The more bits, the more illumination; a sufficiently dense covering of bits, so to speak, increases the odds that enough of them land on everything worth identifying. This is not purely a military phenomenon: indeed the most powerful forces for generating and disseminating information include the World Wide Web, cheap and plentiful video cameras, commercial satellites, and do-it-yourself unmanned aerial vehicles (UAV). Exactly which capabilities appear when can always be debated, but the trend lines are laid in (and may yet be accelerated by fortuitous discoveries here or abroad). To be present is to risk being sensed by one phenomenology or another; the attendant revolution in precision guidance means that to be sensed is to be killed. Thus, to linger transparently is to court death. All this may or may not favor defense over offense (movement creates more signature than hiding). It most definitely favors those who can integrate the various information flows into a coherent picture of the battlespace rather than an opportunistic series of isolated appearances.

In this environment, today's platforms simply cannot pass unnoticed en route to or when engaged in tomorrow's major fights. This fact plus current public aversion to casualties suggest sending large numbers of young men and women overseas to war against secondary enemies (those who cannot possibly directly threaten the United States) need no longer be the "signature" *modus operandi* of the armed services. More and more frequently, greater leverage may come from empowering our allies to do it themselves, particularly when aided by over-the-horizon applications of energy. Empowering is the key concept; telling our friends the location of enemy targets to within the blast radius of their ordnance permits them to defend themselves against larger foes tied to ancient parameters of force. The means by which friends are so empowered are the same bitstreams that feed the metasystem, only this time packaged for delivery rather than ingested organically. Hence, the first mission: extend to friends the information advantage enjoyed by the United States. Should they cease being friends, they cannot drink from

this font of information. Without information, they must fight blindly.

The global transparency mission naturally follows. The surest deterrence to any nation aspiring to hostile great power status may be the certain knowledge that it is under continual watch. As the Air Force argued, US power can be "globally present" even when it appears to be physically detached. Let others so much as open factory doors in the desert, pick up the handset to summon their craft, roll a tank out of its shed onto the road, or launch an aircraft out of a runway deep in the forest and somewhere, somehow, some part of the metasystem knows—and can instantly alert whoever can best train their boresights thereon. This knowledge need not always be converted into engagement; its demonstration alone may dissuade. Thus, the second new mission of the armed forces: to endow the instrumented world transparently so that no country can challenge us in the dark. The evil that lurks in the hearts of humans may forever hide but not the means to convert evil thoughts into evil deeds. Add instant wherewithal to denude will of means, and ill will becomes an aggravation instead of a threat.

The third mission, strategic defense, flows from the second. Over 90 percent of trying to stop a ballistic or cruise missile is finding it. To an aircraft, a Mach 25 missile is a blur; to a photon, however, it hangs in space. The same metasystem that can arm an ally with information and make the entire world transparent to US power also can sweep the skies for air and space threats and dispatch their coordinates to whatever means are chosen for their engagement.

It would be hard to imagine three missions which inherently favor the new air force more. This is so not because the Army and Navy are absent—for they do play—but because they reflect the orientation and *mythos* that has always fueled the Air Force. This is truly *cosa nostra*: "our thing." Their guiding principles—call them dominating medium, topsight, or campaign planning (warfare as a solvable problem of the systemic application of force to a specific end)—follow directly from the inspiration that sent earlier generations to the flight line. Those who recognize a change in the possibilities and employ it in warfare, observed Douhet, have considerable advantages over those who wait until the power of transformational change is used against them. Note that none of these new missions have anything to do with the human mastery of flight. That was yesterday's problem, and one thoroughly solved. It is time for the Air Force, as America's premier technological agency, to move on.

Implications of an Infospheric Air Force

The test of an organizing principle lies in how well it informs the many decisions an institution as complex and vital as the US Air Force must make. The original theory of airpower did precisely that. It gave the organization its mission, put the mission in the context of the other services, suggested how the mission may be fulfilled, prioritized tasks within the mission, steered acquisition strategy (and so fostered the world's greatest aviation industry), defined the essence of being an airman, and contributed to the creation and sustainment of airpower. Today, the Air Force wrestles with seemingly intractable existential problems. If today's vision is to be more than words, it must be the basis by which today's issues are reexamined in a new light, one so powerful it makes the obscure visible and thereby transforms apparent crisis into authentic opportunity.

A vision not reflecting facts risks becoming an illusion. No better example exists than the current F-22 program. To the atmospheric air force, the F-22 is a must have, the next obvious step in a continuous, logical train of sleek machines. The F-22 remains another souped-up, short-range, manned fighter—even if stealthier and laden with more silicon. Perhaps the F-22 can be justified based on a

cold assessment of its costs—which are certainly crowding out many other investments and perhaps opportunities (albeit in a world where everyone else has given up even going against our F-15s). Perhaps an infospheric air force also would buy them. Vision, after all, is the beginning (not be-all) of analysis. But an atmospheric air force cannot help but buy the F-22, as the former head of the Air Combat Command bravely stated, regardless of anything we might know about the threat.

Those who would hold the high ground need to attend to three activities that must become the *raison d'être* of air and space forces: (1) operating militarily in a transparent world, (2) understanding space, and (3) defending the American homeland from aerospace threats. Taken together, these needs are the inescapable facts of the future. They are facts, not problems. A fact is something that cannot be changed. Problems arise from ignoring or trying to alter facts. Air and space forces must focus on the facts of the future and use them advantageously.

In a transparent battlespace, big things make more kinds of signatures than smaller ones. Encasing a human in the life support systems necessary to operate in the high atmosphere or in space requires plenty of weight and cube and even then may be frustrated by the high-G loads necessary for maximum agility. Remove the human body from the flight deck and combat air vehicles can surge ahead. The bandwidth to put "space-derived data into the cockpit" can be redirected to contribute more effectively to other parts of the metasystem. Data need to go to warheads, not task-saturated humans who also have to worry about staying straight and level, breathing, temperature control, urination, and—more importantly perhaps—capture and exploitation. Once the human is removed, small vehicles can quickly become very, very small and very, very fast and pose new problems to defenders. Once pilots are understood as information-processing components—the natural tendency of an infospheric air force—the rational allocation of these functions between carbon and silicon can proceed apace.

UAV illustrate some of the difficulties an atmospheric Air Force engenders for force planning. Just the names today's models have acquired—Hunter, Raptor, Talon, Predator, Dark Star—are good clues that, even unmanned, the UAV is meant to fight rather than just see. Dreams of air-to-air combat among UAV lie just below the surface. Costing several million dollars each, every individual aircraft must be increasingly well protected (and thus add features, and hence cost, and thus . . .). How strange it will seem when someone decides that a $100,000 UAV not only suffices but costs less than the missile otherwise required to shoot it out of the sky. The concept of a flock of expendable UAVs would occur far sooner to an infospheric air force than it would to an atmospheric one.

Second, whither space? Space operators cannot be happy without some way of emulating their air combat cousins. Yet, despite however much real importance space holds for air and ground combat, the chances it can be used as a war-fighting arena, in and of itself, are slight (and were thus even when the Soviets were around). It is bad enough that such urges feed the usual round of institutional fantasies. But they seriously color the space-faring community's approach to "everyone else's" space assets. The belated discovery that our forces could be imperiled with spacecraft-derived information—Saddam Hussein could have seen the left hook coming with overhead imagery—gives birth to a task of shooting such craft from the heavens.

Such a task is problematic. First, it allows others to deny the inevitability of space-mediated transparency on the battlespace under the ill-considered argument that we can eliminate it—all of it—when the time comes. Second, despite the cowboy appeal inherent in "shooting the desperadoes out of the sky," it pushes the armed forces very

close to operational doctrine which would, in practice, target everyone else's spacecraft—perhaps appropriate for a third world war but for no lesser contingency. The "black hull-gray hull" challenge that navies have long faced rarely resolved itself in the injunction to sink all hulls. With satellites so cheap (a simple three-meter capability can soon be purchased for $50 million, no questions asked), and third-party sources so ubiquitous, it will be nigh impossible to find out where the bits are being picked up, how they are being sluiced from satellite to satellite, or even which portal or switch in the self-healing global phone or internet system takes them to their destination.

Instead of preening for pointless battle, the Air Force Space Command ought to pick up its mantle as the premier information force in the world. Virtually everything it owns exists to foster battlespace awareness, connectivity, and strategic intelligence. That understood, the Space Command of the Air Force would be pushing its data as the firmament that makes sense of all other sensors' attempts to paint the battlespace. Working under an infospheric air force, it would not have to be asked twice. Conversely, an atmospheric space command, by short shrifting its information role, risks losing topsight to an emerging ground-based cacophony of small remotely piloted vehicles, high-altitude "pseudolites," and ground sensors. These should all be interactive elements in the metasystem, rather than expedient acquisitions because a metasystem vision and architecture does not exist.

Similarly for space acquisition issues. Should the Air Force pursue a trans-atmospheric vehicle (TAV)? If it seeks to put a pilot in charge, the quest may prove quixotic; there is no medium up there from which to execute the Han Solo flights of fancy that air permits. Yet, if the TAV is understood as a radically cheap way to get a pound into orbit, it opens up a wide variety of vistas, not the least which are for the proliferation of information and command.

Third, the Air Force must become the planet's foremost expert on coping with delivered weapons of mass destruction. These weapons used to separate the professionals in the geostrategic big leagues from the amateurs in the farm clubs. With proliferation, weapons of mass destruction and disruption become strategic equalizers potentially available to any flyspeck nation, as retired Air Force general Larry D. Welch has pointed out. The cheapest and most insidious are weapons of mass information destruction. Close behind are biological weapons capable of being delivered by very small, sensor-evading vehicles. Overseas, they render ports and staging bases unusable for deployment. But they also could hold the American homeland at risk. The threat might come from a ballistic missile—a benign space launch vehicle modified by hostile will—or from a cruise missile launched from a ship-borne container. The capability to touch the American homeland may be such a strategic equalizer that the risks of blackmail and checkmate rise as weapons and delivery means proliferate. Who better to defend the homeland than those who build the metasystem that alerts us to hostile will in actuation?

Some form of active strategic defense must become a competency air and space forces pursue. The former Strategic Defense Initiative Office gave every service a piece; with the Soviets gone, the tough issue of "who's really in charge?" can and must be revisited. Nuclear weapons are no less awesome under a different paint scheme. To argue that a temporary absence of hostile wills lets us ignore hostile means is to forget the value of long-range planning over threat-of-the-moment programming. The dismal prospect of a "peer competitor," while not yet true, may (unless we contemplate it) become a 2015 or 2025 fact. Ignoring facts, as we have said, is a problem. Thus, tomorrow's Air Force must posture itself to command the "high ground" in a real sense. The high ground is the "infosphere," not the atmosphere or the aerospace. To the high

ground's metasystem of knowledge must be added the joint force wherewithal to engage everything an enemy values below.

Tomorrow's Airman Redefined

Central to a redefinition of the Air Force is what it means to be an airman. In World War II, a high percentage of airmen were subject to risk as air crewmen. Today's aircraft are far fewer and more efficiently manned; no more than 1 percent of today's Air Force can be in the air at any one time. Upon how thin a base of pilots at risk can the Air Force rest? Yet, what would substitute as self-definition in an infospheric Air Force?

How have other services coped with similar requirements for change? The Army, heavy and difficult to move, has no choice but to stay with the "getting ready to get ready" template for combat consistent with the traditional cycle of initial response, buildup, counterattack, and consolidation. Perhaps the digitized Army converts tanks into interactive simulators for "virtual mission rehearsal" during the long, slow ride to "buildup"—or perhaps the short work transparency makes of tanks may be too frightening to contemplate. Either way, armor constitutes the skin rather than soul of the Army. At its heart is its self-definition as the will of the American people made manifest in force; this force, in turn, is expressed by being on scene—today in a real context, but over time also in a virtual one. The Marines have gone further than the Army in shedding weight: tanks are a burden that light, lethal, agile forces may aim to shun. They will ride into the future on a self-definition that draws on the chaotic and complex context in which they ply their trade. A marine is a human transformed into the transcendent rifleman. A marine strives to be nothing more nor less than a marine. Similarly, the Navy will understand what transparency can do for the surface fleet. Yet, the Navy was, and is, wedded to the sea before it is wedded to any instrumentality of mastering it. To command the seas and engage adversaries "from the sea" is not necessarily to exert power with mass but to exert discrimination with energy—the medium remains the message for the Navy.

What then of the Air Force? Habituated to being the willful, rebellious little sibling of the Army, the Air Force found it difficult to change without clinging to the instrument that won its independence. Then came ballistic missiles and the shotgun wedding of aero and space. Will the even greater evolution to cyberspace—it is really nothing more than that—create a fuss, even though it is absolutely faithful to the vision of airpower's founders? Of course. The combat airman is the last and emotional vestige of knighthood, the product of the warriors' quest for one-on-one combat. We breed cranky individualism because we believe, when all is said and done, that warfare really is about LeMay being superior to Khrushchev, or Horner being superior to Saddam. An atmospheric air force that seeks a personalized "right stuff" but limits its attainment to rated officers risks an exploitable schism among its various communities—especially as those of "us" in Nomex are surrounded by those of "them" in BDUs, or hospital whites, or office uniforms. All the while the key strokers and techno-wizards greatly outnumber what some of our leaders seem to believe are the few elite "real" warriors. An infospheric air force is inherently based on the teamwork found in the construction of the metasystem. Fortunately, the Air Force chief of staff has set a new course: cooperation, teamwork, and an understanding of the Air Force as a system of teams within teams. There is a base upon which to build.

The Air Force apex always will be defined as the masters of the medium, but in an infospheric air force, the medium of air can yield a bit to the various space media. The notion of the cyber-jock grappling with the dynamic exigencies of the metasystem in real time is not yet here; those who stare into the screen rarely have to react in real

time with "TekWar" tempo. Yet, as the metasystem becomes increasing integrated with sensors and weapons, such real-time control will become increasingly possible, and no one who has spent any time with any masters of the game can doubt their acuity.

And if it is risk that defines the apex, consider that as processing power grows and the spectrum remains fixed, the ability to illuminate, command, and control the battlespace may reintroduce the essentiality of physical presence. Tomorrow's cyber-warrior, strapped to the console, armed with topsight, dedicated to the continuity of illumination, running into the tangible battlespace to build, maintain, or enhance the filigrees of the metasystem will be the definition of grace under pressure.

Implications for Roles and Missions

Such a transition, however necessary and overdue, cannot be made overnight. It must be carefully planned and delicately engineered. In the interim, someone must remain responsible for selecting the technical solutions necessary to mind the atmospheric store. That used to be the service; now it is the Joint Requirements Oversight Council. Within the Air Force, beneficial bureaucratic inertia and persistent affection for the manned air superiority fighter will provide sufficient checks and balances against dizzying change. Moreover, an independent air force is not an autonomous one. Congress, the Joint Staff, many agencies, and the other services must agree to any new self-definition the Air Force advances. Metasystem architects and builders must be funded by the American national security corporation; a corporation that cannot lose its share in commanding the atmospheric market as one of its product divisions comes to a new understanding of the business in which it ought to be engaged. The change we propose is more easily debated than implemented—a frequent characteristic of revolutionary change (witness the airplane and the intercontinental ballistic missile). So, how should we proceed?

If the Air Force understood itself to be organized around not the aging technology of flight but the nascent technology of topsight, it might be able to play the continuous roles and missions debate in a far more constructive manner. Like any shrewd firm, it would cast off low-information missions in favor of high-information ones, strengthen its core competence, and position itself for vigorous institutional life well into the next century, all the while contributing to fostering jointness without risking its own identity.

The current division of services by media is problematic for the Air Force. Take any given mission. Step one in roles and missions is to assign each service responsibility for weapons emerging from their particular medium: ground, sea, or air. Step two, which breeds hairballs, argues that systems emerging from one medium are of course superior to systems from another. Service prestige is put on the line in defense of technical characteristics that play randomly across the face of combat. This is the way to build a litigious bureaucracy, not an institution. The Air Force, by virtue of its need for theory rather than sentiment as its organizing principle, inevitably puts its coherence (rather than end-strength) on the line every time such issues arise.

What should theory say about the Air Force's strategy for missions allocation? Start with the oft-revisited struggled over the "four air forces" in general and close air support in particular. Declaring there is but one air force and three other services also possessing air arms is to deny the facts and fuel continuing debate whenever the embers of fact are fanned. Even so, "one" atmospheric air force disdains every other service's use of aircraft in general, and—when it feels like it—jealously guards the close-air-support mission in particular. So the institutional Air Force does it, but with little enthusiasm—using the wrong aircraft, under the wrong command philosophy, and not nearly as

quickly or responsively as it could, in spite of the valor of its warriors. Meanwhile, the Army makes do with never-satisfactory coordination mechanisms and—then puts all the capabilities it needs in yet another platform for the mission the helicopter—since the Air Force allows it no other choice. The answer for the Air Force is obvious: let this mission and its associated equipment go. The Marines prove a ground force can supply its own jet-propelled airpower organically. Close air support is a necessary but low-yield and low-information component of warfare, one which contributes little to topsight, and rarely—if ever—has strategic effect. As long as armies fight armies, close air support will be necessary. But it is nowhere written in stone that Air Forces must fulfill this responsibility.

A similar debate entails long-range missiles, notably for air defense. It is an Army bailiwick and is oft-contested by the Air Force as an unwarranted intrusion into the deep battle. Here, the Air Force strategy should be obvious: seek the radars and the fire-control internetting and leave the missiles to whoever wants to drag them around. It keeps the topsight over the increasingly nonlinear battlespace and yields the trigger. True, this split is notional as long as fire control and guidance are intimately connected to specific missiles, but such coupling is precisely the wrong way to establish missile guidance in the future. Why could not a Pave Paws radar or an Aegis radar guide a Patriot missile as well as a Patriot radar can? Ultimately, it is the metasystem which informs the firing control mechanism, and the Air Force, if it is smart, will put first claims on the metasystem as the core of the military's information machine.

Today's roles and missions debates seem to look back to the last few days of February 1991. Let others win by that criteria. Instead, look ahead and make claims based on what 2015 or 2025 portends—a global battlespace reapportioned by the microsecond. It is a short hop to extend the Air Force's acknowledged claim to tactical missile defense battle management to overall cognizance of the entire complex information flow required to shoot down another missile. No longer should the Army, Navy, and Air Force take three poorly coordinated approaches—each firing from its own medium. Again, an atmospheric Air Force jealously guards its claim to the right firing platform; an infospheric air forces goes for the jewels.

If the Air Force wishes to contend with other services over platforms, the way to do it is not to waste time arguing over one or another medium but to lay claim to the information-rich components: the Longbow, the Guardrail, the Hawkeye, and (why not?) some day the Aegis battle system (and yes, it matters little who actually drives the vehicles compared to who works the OPCONs and architectures).

An infospheric air force also can take the lead in maturing our understanding of information operations. An infospheric air force realizes that A2 (intelligence) and A6 (computers and communications) no longer can reside in their own little stovepipes separated from A3 (operations). The transition from an atmospheric to an infospheric air force also will give long-term planners in a newly created A5 at least five years of work, examining every aspect of the force and seeing where it fits into the new structure.

A related issue entails what the Air Force should keep organic rather than slough off to the private sector. An atmospheric air force retains its air base orientation, and the result, plain to see, is the retention of so much ancillary functionality that it has far more nurses than operators, with nearly 20 percent of the total Air Force in the health professions. The military's ability to command large forces in single-minded pursuit of worthy aims must be retained. Yet, an infospheric air force would ask which elements need to be military to ensure continuity of information and command operations under stress. It would carefully

review the current practice of outsourcing technical wizardry, lest it be forced to go without in-theater as metasystems are racked with battlefield stress compounded by new forms of information warfare.

Conclusions

We fully expect change will be tortuous and torturous. We also know that "without vision, the people perish." The Air Force stands not before a crossroads but at the edge of a precipice. To affix its affections, theories, and force structures exclusively to aircraft transporting mass to targets is to slide forward into the abyss. Only by braving the chasm can the Air Force ascend to the other side. The lure of descent is familiar to the aviators struggling to retain control of the force, but so were horse and sail to other services in their day.

Will the Air Force fly across like Daedalus or drop like Icarus? If folly is chosen, count on it being proclaimed wisdom. Yet, the inexorable march of contingency leads to one of two outcomes. The better outcome is for splinter groups to arise, chipping off Air Force missions piecemeal and leaving the institution a withering core. The worse outcome is for the ideology of the atmosphere to withstand all challenge—alienating those who see the future with the clarity it presents—until it wakes up to find the revolution grasped firmly abroad by those with few tears left for the Air Force. Either way, if the Air Force fails—fails to do our nation and our allies the favor of succeeding—we leave it to historians of the next century to discover the answer to our final question: why did the Air Force—given the choice of living in fame or going down in flame posed in its own song—choose descent and demise?

The leap from atmospheric to infospheric air force is the next logical step, as paradoxical as it may seem. Air forces have capitalized on the speed, range, freedom of maneuver, and vantage their medium provides. Yet, nothing travels faster than information. Nothing impedes the distance knowledge can travel. Nothing makes movement more intelligent, economical, and fruitful than information. And nothing else would provide the vantage of a metasystem. Atmospheric solutions sufficed until technology permitted multiple solutions from any medium. The metasystem, however, demands an integration of exoatmospheric components with those provided from air and surface. This is not the vision or role the Army, Navy, or Marine Corps are in a natural position to advance on, although they may lay claim to bits and pieces, thereby frustrating the larger aim. This is the Air Force's game to win or lose. This essay argues that the hangar door leading to the open skies of the infosphere is ajar, but that the Air Force—if it is to retain its right to be—must roll out and take off without delay.

An Operational Analysis for *2025*: An Application of Value-Focused Thinking to Future Air and Space Capabilities

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Executive Summary

In the summer of 1995 the Air Force chief of staff tasked Air University to conduct a year-long study, ***2025***, to "generate ideas and concepts on the capabilities the United States will require to possess the dominant air and space forces in the future . . . detail . . . new or high-leverage concepts for employing air and space power . . . detail . . . the technologies required to enable the capabilities envisioned." To support this goal an operational analysis was conducted to identify high-value system concepts and their enabling technologies in a way that was objective, traceable, and robust. This analysis determined which of the ***2025*** system concepts showed the greatest potential for enhancing future air and space capabilities and which of their embedded technologies have the highest leverage in making the high-value system concepts a reality.

A model, ***Foundations 2025***, which reflected the overall values held by the ***2025*** participants was developed to quantify and compare different system concepts' contributions to future air and space capabilities. ***Foundations 2025*** is distinguished by the large number of system concepts that can be analyzed, the 30-year focus into the future, and the fact it was developed through a bottoms-up approach. ***Foundations 2025*** offers a potential new framework for future air and space doctrine and can be easily modified (broken into three separate models: *awareness*, *reach*, and *power*) by Air Force major commands for use in their mission area analysis process. Thus, the model presented is an aid to current and future senior decision makers concerned with the employment of air and space power.

The ***2025*** study produced a number of excellent system concepts for employing air and space power in the future. Analysis of the highest value system concepts indicated that the effort to occupy the "high ground" of the future will require air and space forces to possess increased *awareness* and to control the medium of space. The five highest value system concepts were

- Global information management system
- Sanctuary base
- Global surveillance, reconnaissance, and targeting system

- Global area strike system
- Uninhabited combat air vehicle

The following six system concepts scored below the top five but were clearly ahead of the others:

- Space-based high-energy laser
- Solar-powered high-energy laser
- Reconnaissance UAV
- Attack microbots
- Piloted SSTO TAV
- Uninhabited air-launched TAV

These conclusions regarding the rankings of the system concepts were not affected by any reasonable changes of the weighting scheme in the Value Model.

The study also included an assessment of the enabling technologies on which the system concepts depend. The analysis explicitly took into account the number of system concepts each technology supported, the degree to which each system concept depended on it, and the importance of the system concept. Six high-leverage technologies stood out because they are important to a large number of high-value system concepts:

- Data fusion
- Power systems
- Micromechanical devices
- Advanced materials
- High-energy propellants
- High-performance computing

The major surprise among these results was the importance of continued breakthroughs in the area of power systems. Other moderate-leverage technologies were also important but contributed to only three or four of the high-value system concepts:

- High-energy laser systems
- Artificial intelligence
- Optics
- Aerospace structures
- Image processing
- Communications

Advances in these areas show promise to open the way to air and space systems that would dramatically improve the effectiveness of air and space power employment to achieve the US military objectives.

Chapter 1

Introduction

The long range planning process in our Air Force is broken. If we are going to be relevant in the future, we've got to somehow break free of the evolutionary nature of the planning process.
—Gen Ronald R. Fogleman

With these few words, the chief of staff of the Air Force, Gen Ronald R. Fogleman, challenged the participants of the ***2025*** study to generate ideas and concepts on the capabilities the United States will require to dominate air and space forces in the future. When General Fogleman assigned the responsibility for ***2025*** to Air University, he directed that the final product be a collection of white papers detailing findings regarding air and space capabilities required for future warfare, new or high-leverage concepts for employing air and space power, and the technologies required to enable the required capabilities.[1]

Meeting the Challenge

In response to General Fogleman's tasking, Air University devised a four-phase study process to stimulate creativity, generate ideas, and evaluate concepts (fig. 1-1).

The Preparation Phase exposed participants to a wide variety of creative thinking and problem-solving concepts. This phase laid the groundwork for the Idea Generation Phase in which the participants developed plausible alternative futures as well as future system concepts and technologies. Inputs for the Idea Generation Phase were gathered from a worldwide data call which produced more than 1,000 submissions.

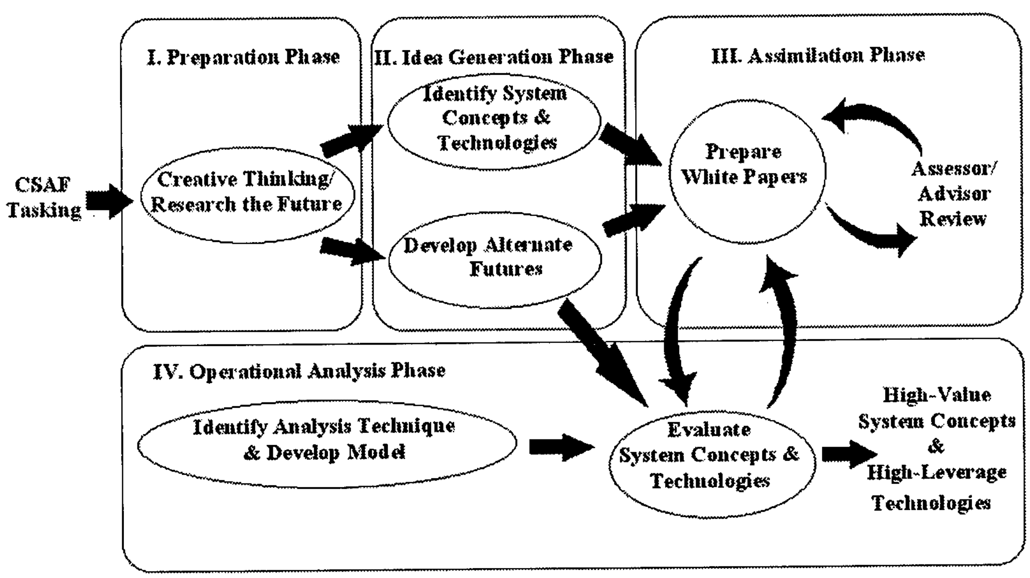

Figure 1-1. *2025* Study Process

In the Assimilation Phase, the participants were organized into specific writing teams based on operational experience. Each team was given a particular area to consider and concentrate their research (appendix B, table 4). After postulating the required capabilities of the future Air Force, each team developed system concepts and technologies from the Idea Generation Phase to satisfy these future requirements.

This phase produced a large number of system concepts which were described in varying levels of detail, which provided widely different kinds of operational capabilities, and which depended on different levels of advancements in different areas beyond current technology. Clearly, not all of these system concepts could be developed, nor could all of the technologies be aggressively pursued. The study needed to prioritize the relative importance of both future system concepts and their enabling technologies.

An operational analysis was conducted with the other three phases to aid in this prioritization. Its purpose was to evaluate system concepts and technologies developed in the white papers; specifically, it had three objectives:

1. To assess the potential operational utility of future air and space system concepts;
2. Identify the high leverage technologies required by those system concepts; and
3. Provide an objective, traceable, and robust analysis.

Figure 1-2 shows the methodology used for the operational analysis. The left column reflects the evaluation of system concepts for operational utility, while the right column identifies and evaluates the underlying high-leverage technologies.

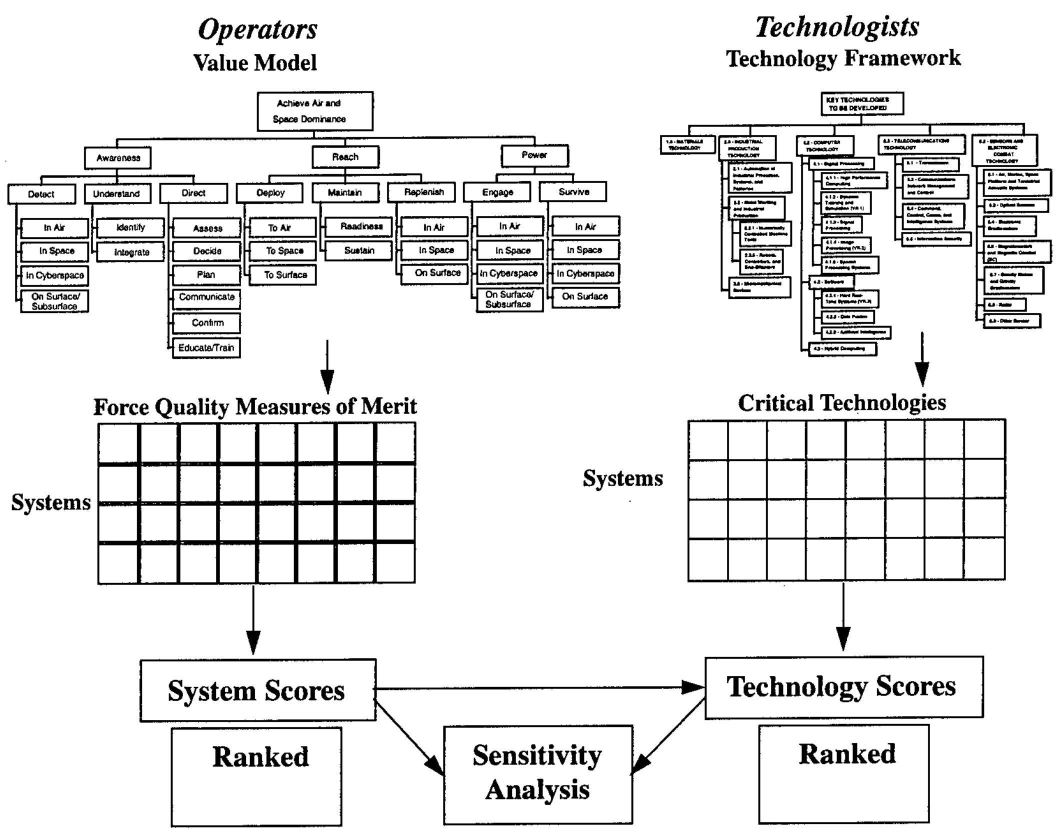

Figure 1-2. Operational Analysis Methodology

For the system concept evaluation, this model used a hierarchy of objectives, functions, and tasks, which represented the objectives necessary to underwrite air and space power in the next 30 years. For the technology evaluation, the framework was a logical structuring of technology areas that were mutually exclusive and collectively exhaustive. These hierarchies provided the desired characteristics of objectivity and traceability. The desired robustness quality was assured by performing a sensitivity analysis at the conclusion of the system concept and technology scoring. Specifically, the sensitivity analysis was conducted across a number of plausible alternate futures (see "Alternate Futures" section of chap. 2).

Overview of Report

This report describes in detail the operational analysis conducted as a part of the ***2025*** study and introduces ***Foundations 2025,*** a value model for evaluating future air and space capabilities. Chapter 2 discusses the methodology used to develop the ***Foundations 2025*** value model, the technology framework, and how each was used to evaluate the ***2025*** systems and underlying technologies.[2] The results of the analysis are presented in chapter 3 and conclusions are summarized in chapter 4. Several appendices are included and provide the supporting data for chapters 3 and 4.

Notes

1. Message from Gen Ronald R. Fogleman to Air University, 23 December 1994.

2. From this point forward we will use the term *system* when referring to the system concepts. The authors recognize that *system* carries the connotation of existing hardware, but it is less cumbersome, and all of the systems scored here are futuristic.

Chapter 2

Methodology

This chapter outlines the methods that ***2025*** used to evaluate systems and technologies. It covers the development of the value model to score the systems, the system identification process, the system scoring procedures, the technology identification, and scoring procedures and ends with an evaluation of which sector (public or commercial) will develop the future technologies.

Challenges

A primary goal of the ***2025*** operational analysis (OA) was to identify the ***2025*** systems that offer the greatest potential to support future air and space operations. To meet this goal, the Analysis team's challenge was to develop a methodology that satisfied a diverse set of criteria. First, the ***2025*** OA needed to be compatible with the Air University academic calendar year. It also needed to be capable of quick implementation after the Air Command and Staff College and Air War College students completed their white papers, which contained conceptual descriptions of the systems.

Second, because ***2025*** was a study about 30 years into the future, the system descriptions in the white papers lacked engineering detail. Therefore, the OA methodology had to use human judgment about operational capability and key enabling technologies.

Third, while the values of the current senior leadership of the Air Force are well documented in strategies, policies, and directives, it is far more difficult to predict what will be important to future leaders.

Fourth, to prevent one set of views or interests from unduly influencing the results, the evaluation methodology had to be free of institutional bias. The methodology should neither unfairly favor nor unduly penalize any potential ***2025*** systems.

Fifth, the results had to be traceable, since the ***2025*** system evaluation results would be subject to scrutiny. The Analysis team members would need to explain for any given system or technology how and why it was scored. The study participants and Air Force senior leadership would be far more likely to accept the results if they could understand clearly how the systems were evaluated.

Sixth, the OA methodology had to be robust to apply across a wide range of potential future environments postulated by the ***2025*** Alternate Futures team. Each future described a different political, technological, and social environment (see the "Alternate Futures" section). The OA methodology had to be able to capture different priorities assigned to air and space functions and tasks in these alternate futures.

The 2025 Operational Analysis

The Analysis team developed the four-step approach to satisfy the requirements previously described (fig. 2-1). This section contains a very brief overview of the ***2025*** OA process; the following sections describe each of the four steps of the process in detail. First, the Analysis team had to choose the most appropriate analysis methodology for the OA. After considering the advantages and disadvantages of many possibilities, the team selected an approach known as Value-Focused Thinking (VFT).[1] Second, to implement VFT, the team had to find a *value model* to quantify and compare

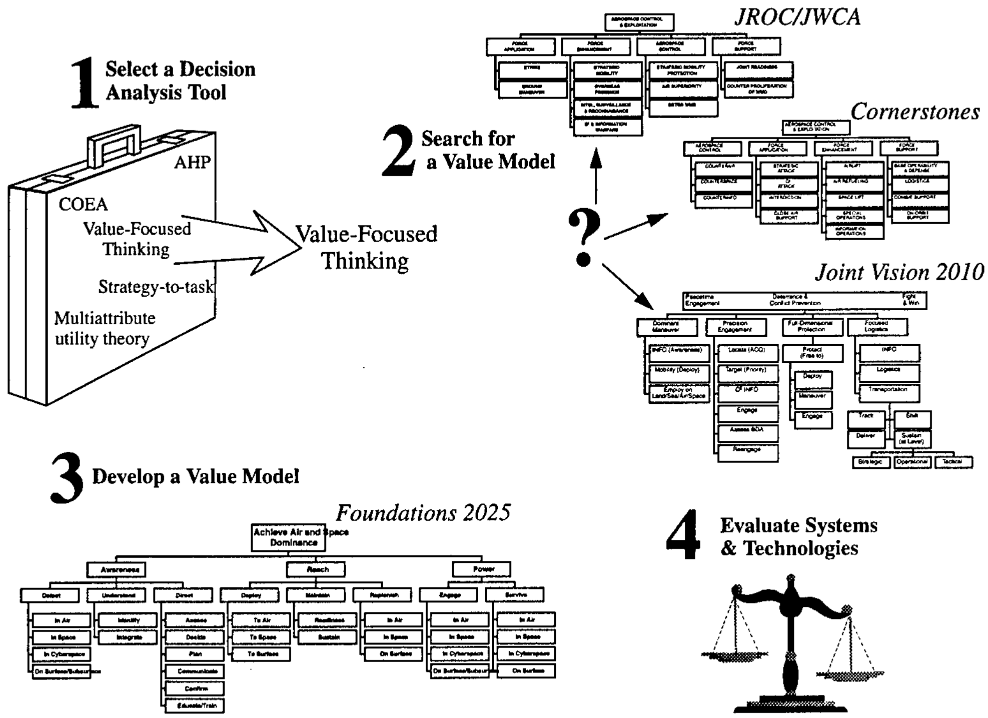

Figure 2-1. *2025* OA Process

the contributions of the systems proposed by ***2025;*** therefore, the next step was a comprehensive search for a suitable existing value model. Third, when no suitable alternative was found, the Analysis team developed a new value model, ***Foundations 2025***. The fourth step used the value model to evaluate ***2025*** systems and then the technologies that will be required to develop these systems.

Selecting a Decision Analysis Tool

The first step in the ***2025*** OA was to find the analytic approach that best satisfied the study requirements. The challenge facing the Analysis team could be stated simply: Given a large number of ideas for future systems and technologies, how should the Air Force evaluate and compare the relative "worth" of competing alternatives?

Comparing Analysis Tools

Each analysis approach has particular strengths and weaknesses; therefore, the Analysis team examined them in relation to the challenges of the ***2025*** study discussed previously. The team considered the following analysis techniques:

- "most-to-least dear" with no criteria
- qualitative comparison with criteria
- simple quantitative comparison matrix
- value-focused thinking
- analytical hierarchy process
- strategy-to-task
- futures-to-strategy-to-task
- common operational objectives of the armed forces
- cost and operational effectiveness analysis

These choices are listed in order of increasing depth of the analysis. In selecting an analysis technique for this task, the most important tradeoff is between the level of engineering detail and the available time. The first few methodologies require the least amount of detail concerning the evaluated systems, while the last few demand considerable engineering detail. At one extreme ("most-to-least dear"), a group of experts can review the alternatives and can rank them subjectively. At the other extreme, a full cost and operational effectiveness analysis can be done, as is usually done before starting the development phase of any new major weapon system acquisition.

The first approach is "most-to-least dear" and has no criteria. This technique is sometimes referred to as the "bunch-of-smart-people-around-a-table" approach. This method can be accomplished quickly; however, it is difficult to replicate. This approach is not robust, and it lacks objectivity and traceability. The second approach, qualitative comparison with criteria, is slightly more rigorous, but the subjective rationale again lacks objectivity and traceability. The next approach, a simple quantitative comparison matrix, provides more rigor, but with the large number of systems across all air and space capabilities, the team felt a comparison matrix approach would not adequately distinguish between competing systems.

The fourth approach, value-focused thinking, was the technique used in the Air University ***SPACECAST 2020*** study of 1994.[2] Instead of highly detailed system data, VFT employs user-defined scoring functions to compare the performance of alternate systems. Systems that perform well on these scoring functions receive high-value scores. The VFT process is traceable because system evaluations are based on defined scoring functions. This approach capitalizes on a strength of the ***2025*** process—lots of expert judgment.

The fifth technique, the analytical hierarchy process (AHP), ranks alternatives, but its several drawbacks limited its usefulness for this study. AHP requires pairwise comparisons between systems with respect to each criterion. The large number of systems made such comparisons cumbersome. Introductions of new systems to the study require AU comparisons to be repeated.

The next three techniques—strategy-to-task, futures-to-strategy-to-task, and common operational objectives of the armed forces—require an operating concept and a known strategy. The ***2025*** study, by its nature, moves beyond the point where well defined operating concepts support a known strategy.

At the end of the spectrum is the cost/operational effectiveness analysis (COEA) technique. This approach is the most rigorous and time consuming because it demands detailed engineering data which does not exist. Furthermore, COEAs typically take several months or sometimes years to complete.

The Best Approach for *2025*

After considering the advantages and disadvantages of the various approaches, the Analysis team believed VFT offered the best compromise for satisfying the OA requirements. VFT was particularly suited for structuring the subjective judgments required to evaluate the systems. It also allowed the OA to be completed in the limited time available and, because VFT was used in the ***SPACECAST 2020*** study, it was well understood and accepted by the Air University senior leadership. In addition, once a value framework was built using VFT, it was easy to assess systems across several alternate futures. Finally, the VFT methodology enables the OA to be objective, traceable, and robust.

Value-Focused Thinking

VFT begins by structuring the decision maker's values into a hierarchy of objectives. Top-level objectives describe aspirations that are most important to the

decision maker. Objectives are decomposed until desired force qualities can be specified and measured. Weights are assigned to signify the relative importance of objectives at every level.

In the VFT methodology, we use several key terms—*value, objectives, functions, tasks, subtasks, force qualities, measures of merit, scoring functions, value model,* and *weights.*

Value

The most important concept in VFT is value. Ralph L. Keeney says, "Values are what we care about. [Values] should be the driving force for our decision-making."[3] The fundamental precept of VFT is that values are principles used for evaluation.[4]

Keeney asserts that thinking about values is constraint-free thinking.[5] By not limiting oneself to predetermined alternatives in the search for solutions, innovative answers can be developed. This philosophy complemented the creative thinking exercises of ***2025***.

Objectives, Functions, Tasks, and Subtasks

In VFT, values are made explicit with objectives, and a hierarchy of objectives is constructed that supports the decision maker's values.[6] Specific, lower-level objectives support the general, overarching objectives. The Analysis team used the terms *objective, functions, tasks,* and *subtasks* to designate the tiers in the hierarchy, from highest to lowest, respectively.

Force Qualities

In VFT terminology, a force quality defines a desired attribute of a system to achieve a subtask. For example, if the subtask is to "identify," a corresponding force quality might be "accurate." According to Keeney, "[force qualities] should be measurable, operational, and understandable."[7]

Measures of Merit and Scoring Functions

Each force quality has a measure of merit that is the metric used to gauge system performance. Each measure of merit has a range of outcomes, from worst to best. To continue with the previous example, if the subtask is "identify" and the force quality is "accurate," then a measure of merit could be "percent of correct identifications."

VFT scoring functions provide a quantitative means for measuring the relative system performance for each measure of merit. For example, if the measure of merit is percent of correct identifications, the corresponding scoring function might convert a system performance of "83 percent correct identifications" into a score of 92.

Because scoring functions operationalize the measures of merit, they are the building blocks for assessing system performance. The domains (horizontal axes) of the scoring functions are the measures of merit; the ranges (vertical axes) are the corresponding value scores. A scoring function's domain may be quantitative or qualitative, but its range must be quantitative. While domains are different, ranges must be the same. Typical ranges are [0,1], [0,10], or [0,100]. The development of these functions is a significant analytical task, since analysts must discern the decision makers' values for the full range of the measure of merit for each force quality.

Many types of scoring functions exist; the relationship between subtasks and force qualities dictates the appropriate form. One of the simplest scoring functions is the linear scoring function (fig. 2-2a). If a decision maker chooses a linear function, the underlying implication is that each incremental increase in performance is valued just as much as the preceding increment.

The linear scoring function has the advantages of easy construction and computation; however, decision makers frequently do not assign value linearly. For example, the value placed on system performance often experiences diminishing marginal returns (fig. 2-2b). In other words, each incremental increase in performance is valued less than the preceding increment.

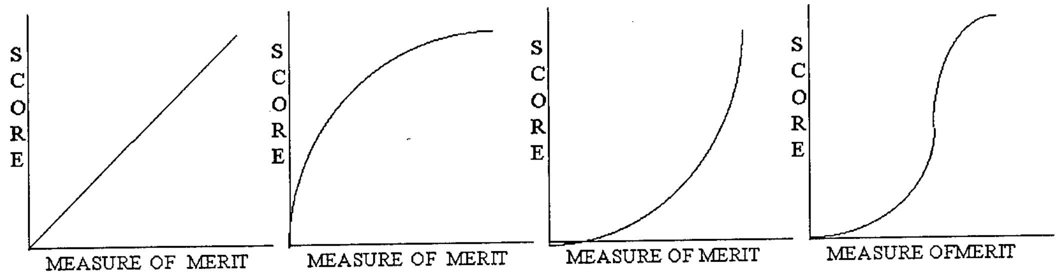

Figure 2-2a
Linear Returns

Figure 2-2b
Diminishing Returns

Figure 2-2c
Increasing Returns

Figure 2-2d
Increasing-then-Diminishing Returns

Figure 2-2. Sample Scoring Functions

Another way of explaining diminishing returns is to say that some level of performance is "good enough."

Another phenomenon is that of increasing marginal returns (fig. 2-2c). Here each incremental increase in performance is worth more than the preceding increment. Under these circumstances, the decision maker admits there is a certain threshold of performance that must be met before the system has substantive value.

Another popular scoring function is the S-curve, which initially reflects increasing returns, then switches to diminishing returns (fig. 2-2d). The preceding four examples are the most common scoring functions; however, as long as the objective is to maximize value, any monotonically increasing (i.e., never decreasing) representation is possible. Clemen,[8] Keeney,[9] and Winston[10] discuss techniques for deriving scoring functions.

Value Model

A value model is the hierarchical representation of objectives, functions, tasks, subtasks, force qualities, measures of merit, and scoring functions. ***Foundations 2025*** was the value model developed for ***2025***. A value model, also called a value tree by some authors, is a branching structure, with the most fundamental decision maker objectives at the top. Keeney uses the term *fundamental objectives hierarchy,*[11] and states, "The higher level objective is defined by the set of lower-level objectives directly under it in the hierarchy."[12] In other words, the lower-level objectives completely specify their higher-level objective.

Clemen describes five specific characteristics of a value model:

1. It should be complete, encompassing all important facets of the decision.
2. It "should be as small as possible."[13]
3. The force qualities should allow straightforward measurement.
4. Objectives should only appear once in the tree.
5. The decision maker should be able to think about and treat the branches of the tree separately.[14] Combining the first, fourth, and fifth characteristics above yields two properties—the objectives must be mutually exclusive (only appear once and can be treated separately) and collectively exhaustive (encompass all that the decision maker values).

Analysts work with decision makers to develop value models. Sometimes candidate value models already exist, at least partially, within an organization. In other cases, a new value model must be constructed. Keeney provides further back-

ground and techniques for developing value models.[15]

Figure 2-3 shows a notional value model. Under the objective, there are three functions (first level of subordinate objectives). Under functions are corresponding tasks (second level of subordinate objectives). In this example, function 2 has two tasks (A and B). Tasks can also have subtasks (not included in this example), and tasks and subtasks can have one or more force qualities that characterize success at this task. Task A has three force qualities and Task B has one force quality (fig. 2-3). For each force quality, one or more measures of merit must be identified, each of which has a corresponding scoring function.

Weights

After the hierarchical structure of the value model is complete, the decision maker must determine the relative importance of the functions, tasks, force qualities, and measures of merit. Numerical weights are assigned across each tier of the value model. These weights must satisfy certain mathematical requirements. Weights must be between 0 and 1, and for each function or task, the weights of the immediately subordinate functions, tasks, subtasks, and force qualities must sum to 1.00. Figure 2-4 shows weights applied to the earlier notional value model. Note that the weights of the three functions sum to 1.00, as do the weights of the two tasks under function 2 and the three force qualities under task A. Note also that when a subordinate level contains only one box, its weight is necessarily 1.00.

Applying the Value Model

After the value model is completed and weights has been assigned, the evaluation of systems can be accomplished. The computations are straightforward. First, for system, raw scores are initially computed by using the applicable scoring functions. If a particular measure of merit does not apply to a given system, the raw score is zero. Next, weighted scores are calculated by multiplying the raw scores by the product of all the weights in the branch that leads (bottom-up) from the measure of merit to the highest-level objective. Finally, a total

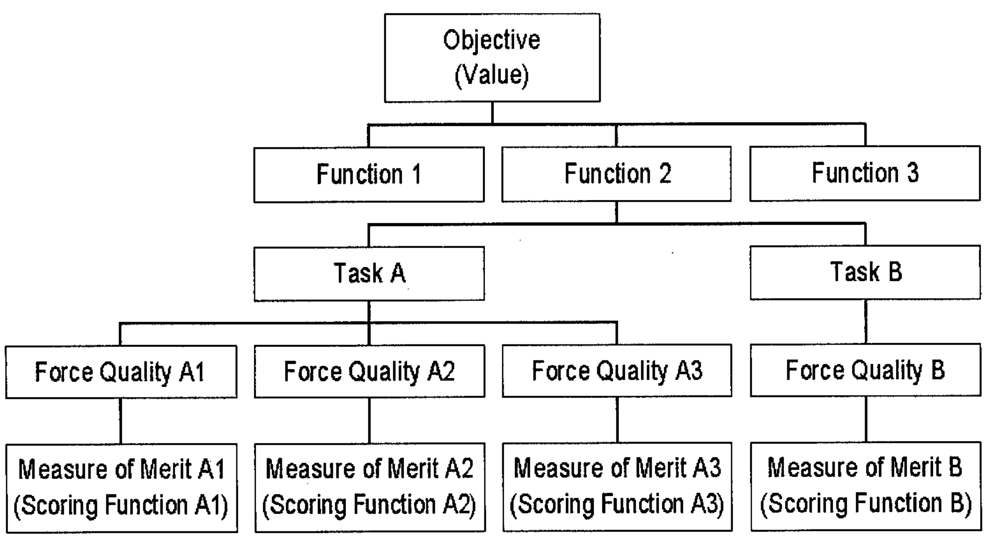

Figure 2-3. Notional Value Model

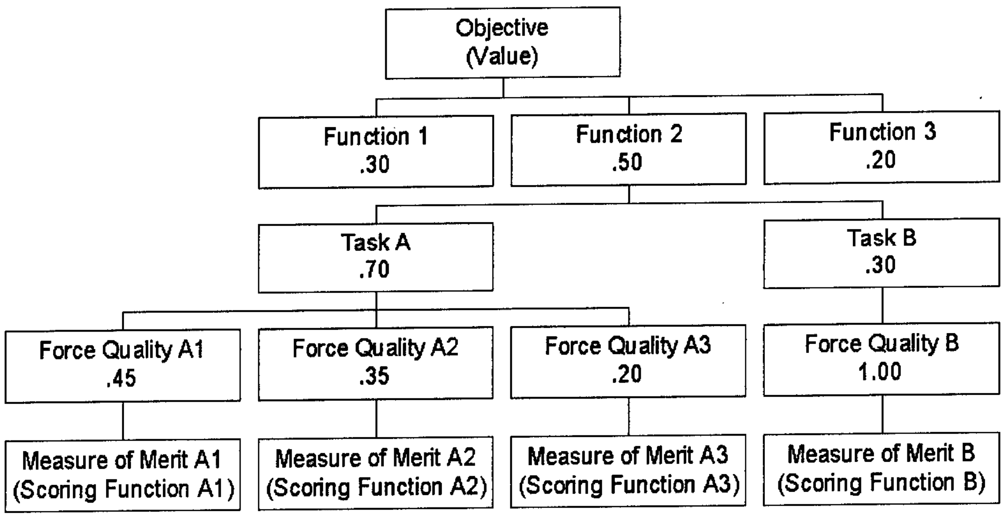

Figure 2-4. Weights Applied to Notional Value Model

system score is found by summing the weighted scores. The system with the highest score is the "best."

Using the earlier notional example (fig. 2-4), assume system X has raw scores of 37, 62, 18, and 83 for measures of merit A1, A2, A3, and B, respectively. The resulting score for function 2, S(function 2), is

$$\begin{aligned} S(\text{function 2}) &= \{[(37)(0.45)(0.7)(0.5) + \\ &\quad (62)(0.35)(0.7)(0.5) + \\ &\quad (18)(0.2)(0.7)(0.5)] + \\ &\quad (83)(1.0)(0.3)(0.5)\} \\ &= 5.82 + 7.59 + 1.26 + 12.45 \\ &= 27.12 \end{aligned}$$

Similar operations are performed for every branch of the value model, then they are summed to compute the total score for system X.

The Search for the *2025* Value Model

After the Analysis team selected VFT, the next step was to either select an existing value model or develop a new one. Identifying a current model proved to be a daunting task because of the scope of the study and the focus on the far future. The participants ranged across all of the military services and included allies, civilians, government officials, and industry. Any potential model also had to satisfy Clemen's five criteria.[16]

The Analysis team initially searched for a national level strategic document that identified priorities for future air and space forces. The following sources were investigated:

- *A National Security Strategy of Engagement and Enlargement*
- *National Military Strategy of the United States of America*
- *Defense Planning Guidance*
- Joint Requirements Oversight Council (JROC)/Joint Warfighting Capabilities Assessment (JWCA) categories
- *Global Presence and Global Reach, Global Power*
- Common operational objectives of the armed forces
- Draft AFDD-1
- *Joint Vision 2010*
- *Cornerstones of Information Warfare*

A National Security Strategy of Engagement and Enlargement[17] represents the views of the president. It provides a high-level strategic view of the national defense policy but does not support or provide any

definitive characteristics that could form the basis of a value model. The *National Military Strategy of the United States of America* (NMS), by the chairman, Joint Chiefs of Staff (CJCS), also has a grand strategy perspective.[18] The NMS contains a framework, but the task breakdowns have too much overlap. The *Defense Planning Guidance*[19] is focused on the near-and midterm budget cycle; therefore, it does not support the visionary requirements of ***2025***.

The former vice CJCS, Adm William A. Owens, produced a set of JROC/JWCA categories to support the planning and analysis integration of the service program objective memoranda (fig. 2-5). While the JROC/JWCA framework was designed to be visionary, it also has considerable overlap. For example, the tasks of to "deter weapons of mass destruction (WMD)" and "counter proliferation of WMD" are not mutually exclusive, nor are the tasks of "ground maneuver," "strategic mobility," and "strategic mobility protection."

The secretary of the Air Force published the *Global Reach, Global Power*[20] and *Global Presence*[21] series of documents to promulgate the high-level vision of the Air Force of the future. But like the president's national security strategy, these documents do not define key functions required to create a hierarchical value framework.

Another interesting approach, common operational objectives of the armed forces, is based on the work of Lt Gen Glenn A. Kent, USAF, Retired.[22] This document contains a strategy-to-task focus that could be suitable; however, like the defense planning guidance, it focuses on midterm planning years. This approach has two other qualities that made it unsuitable for ***2025:*** it requires more engineering definition of the systems and concepts being evaluated than is available, and it assumes a working concept of operations. Moreover, it assumes a known future strategy.

The Analysis team next looked to doctrinal publications as a potential source for a value model framework because doctrine is specifically written to provide guidance on how to think about air and space capabilities without being tied to a particular time period. The Air Force is currently writing a new doctrinal pamphlet, *Air Force Doctrine Document: Air Force Basic Doctrine - 1* (AFDD-1).[23]

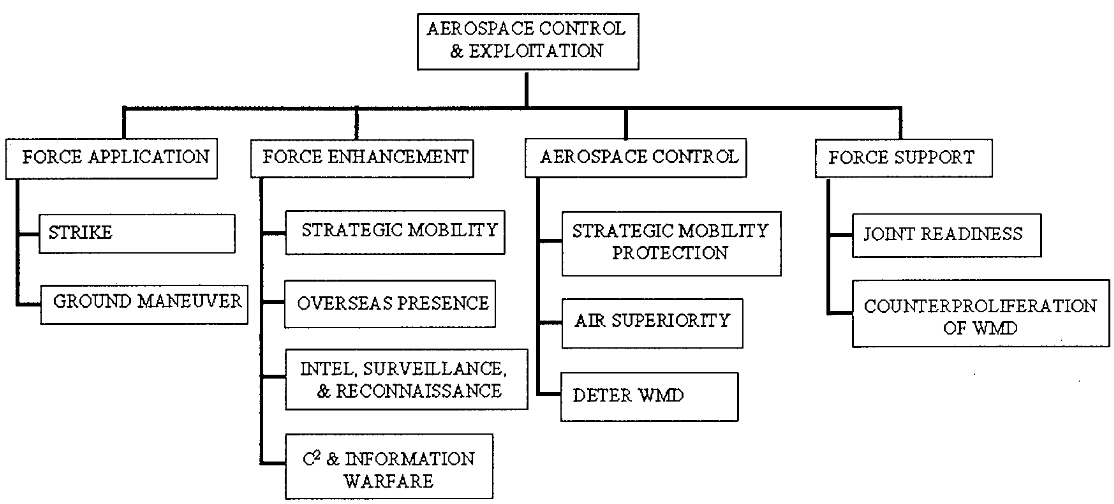

Figure 2-5. Value Model Based on JROC/JWCA Categories

Figure 2-6 shows a candidate value model based on the first draft of AFDD-1. This framework has several shortcomings. First, the tasks of "strategic attack," "interdiction," and "close air support" contain considerable overlap. Next, "information operations" is not integrated into the framework but rather is represented as a series of traditional functional tasks such as "C^4," "intelligence," and "weather service." The goal of the ***2025*** study was to propose and evaluate systems that are employed to dominate air and space; it was not concerned with how we are currently organized to perform traditional functions.

Another doctrinally based candidate for the ***2025*** value framework was based on a document from the Joint Staff, *Joint Vision 2010* (fig. 2-7).[24] As its title states, *Joint Vision 2010* focuses on the future 15 years hence, not 30 years. In many cases, the acquisition process for the systems of 2010 has started already, so this model is not sufficiently visionary. On the other hand, *Joint Vision 2010* contains a number of interesting departures from current service doctrines, especially in the focus on precision engagement and the vision for information and maneuver dominance. However, the model contains significant overlap in the tasks of "mobility (deploy)," "deploy," "maneuver," and "transportation." Because of the overlap, and since it did not look far enough into the future, the Analysis team rejected the *Joint Vision 2010* model.

The existing model with the closest fit to the ***2025*** requirements was in the document *Cornerstones of Information Warfare*, released by the chief of staff and the secretary of the Air Force in late 1995.[25] *Cornerstones* was written "to provide a sound and widely accepted basis from which we can adapt Air Force doctrine to the Information Age."

Figure 2-8 shows the *Cornerstones* hierarchical framework. *Cornerstones* seemed

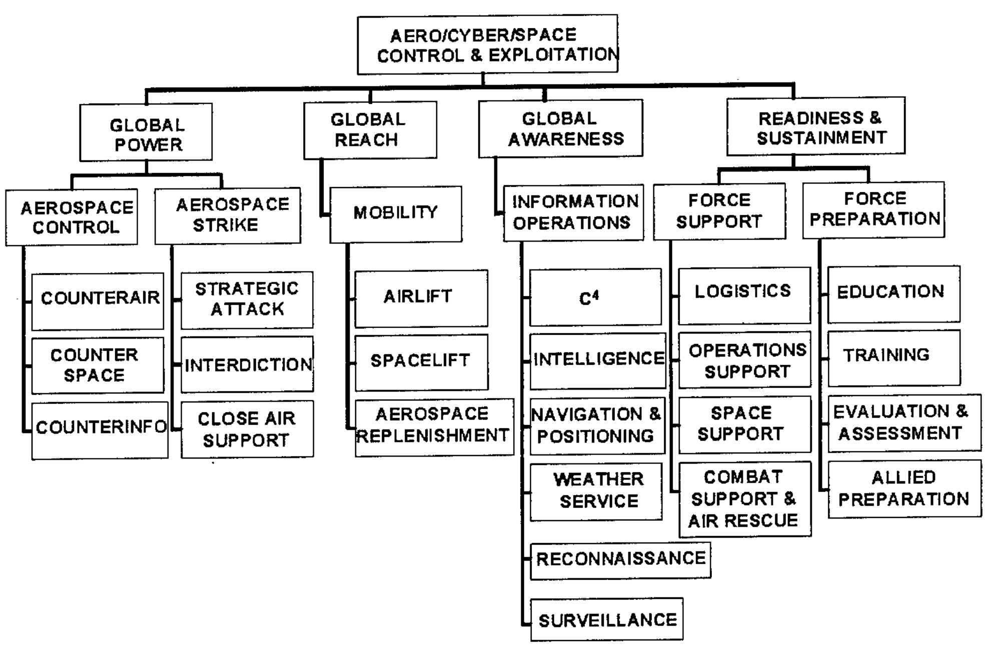

Figure 2-6. Value Model Based on AFDD-1

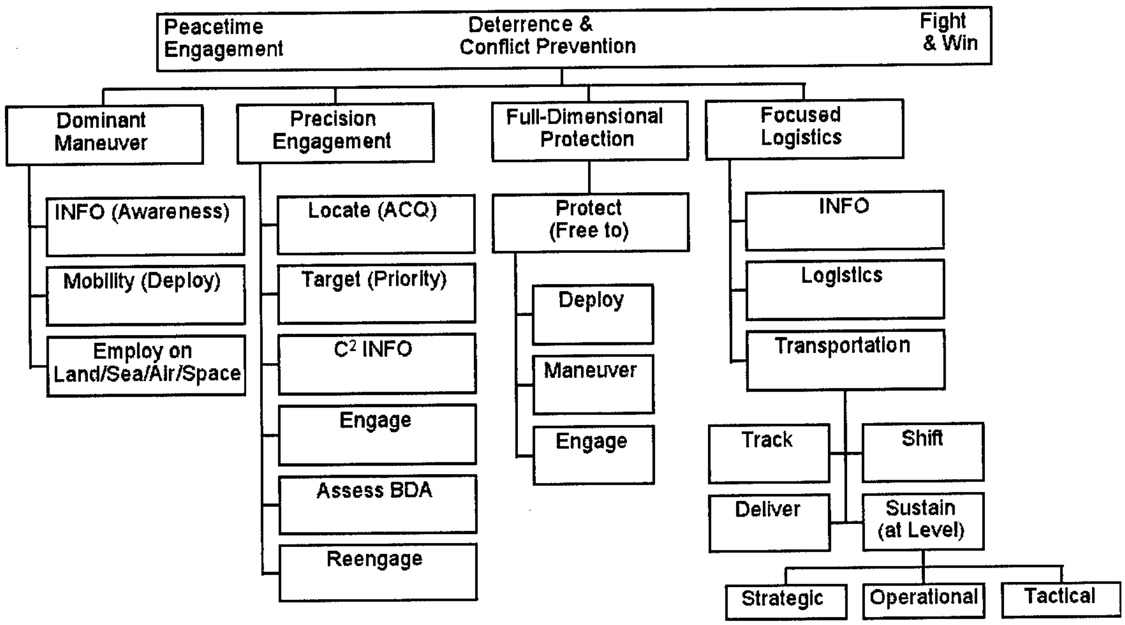

Figure 2-7. Value Model Based on *Joint Vision 2010*

to accommodate most of the tasks and functions envisioned in ***2025***. It addresses information warfare in a realistic and rational manner and is written with time-honored terms that are easily understood by the study participants. Except in the area of information operations, it has the only mutually exclusive and collectively exhaustive structure of any of the existing frameworks and, therefore, provides a sound mathematical basis for analysis. While an excellent document in many respects (its view of information warfare as another technique for mission accomplishment is noteworthy), *Cornerstones* continues to maintain a number of traditional "stovepipe" functions. As a result, the institutional biases inherent in the model could have stifled the creative process of ***2025***.

After reviewing the full range of potential value models, the senior leadership of ***2025*** determined that none of the models met the requirements of ***2025***. Each model was grounded in near- or midterm thinking, and none seemed to think "outside of the box" about new ways to employ air and space forces in the far future. Furthermore, each contains traditional biases focusing on how the Air Force is organized, while ***2025*** addresses the dominant employment of air and space forces in the year 2025 and beyond. The only solution was for the Analysis team to develop a new framework to capture the visionary thinking that took place during the study.

Developing the *2025* Value Model—*Foundations 2025*

Developing the ***2025*** value model was a key part of the analysis process. The work began early in ***2025***, and it continued for the duration of the study. The final value model, ***Foundations 2025***, was so named because it provided the basis for the ***2025*** operational analysis.

This section traces the evolution of the ***Foundations 2025*** value model. The process of developing the model began by identifying the model's overarching objective. Next, the Analysis team built tasks and functions from the bottom up, an atypical approach to building value models. When the task-function-objective framework

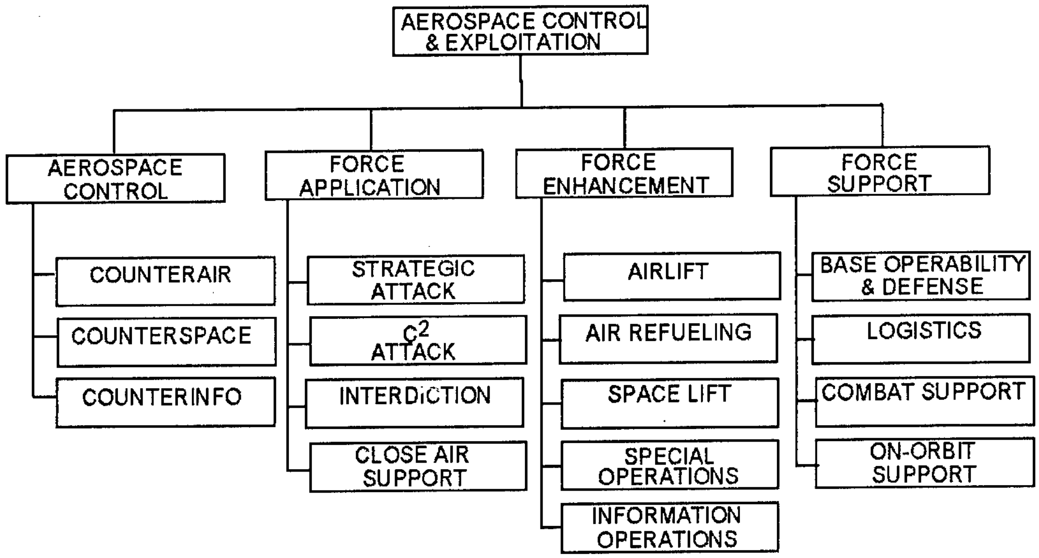

Figure 2-8. Value Model Based on *Cornerstones*

was complete, the team completed the value model by creating force qualities, measures of merit, and scoring functions.

Objective

Before making any progress toward developing a value model, the Analysis team needed a clear statement of the objective. As stated in the "Introduction," General Fogleman tasked the ***2025*** participants to generate ideas and concepts on the capabilities the United States will require to dominate air and space in the future. This statement was translated into the overarching objective, "Achieve Air and Space Dominance," that became the top tier of ***Foundations 2025***.

A Bottom-Up Approach

With this overarching objective defined, the Analysis team could start specifying subtasks, tasks, and functions. Early on, the team departed from the usual approach to constructing a value model. Conventional value models are built in a top-down fashion; each level of the model hierarchy is derived from the next higher level. In contrast to the top-down method, a bottom-up approach makes no *a priori* assumptions and does not establish preconditions. The bottom-up approach should result in less institutional bias.

Tasks and Subtasks

The first step in the bottom-up process was to meet with each of the ***2025*** white paper writing teams to gather their specific notions of the required *tasks* and *subtasks* of future air and space forces. (At this stage, the terms were interchangeable, so both are called tasks.) The teams held diverse views on task specification, but the ideas could all be characterized as some form of action. As a result, action verbs were used to specify tasks required for the employment of air and space forces in the year 2025.

Figure 2-9 shows the disparate tasks that resulted from brainstorming sessions with the ***2025*** teams. In this figure, the superscript after the task shows the letter designation of the team that identified the task (table 4). The final tally was 109 different tasks; the first step in the

evolution of the ***Foundations 2025*** model was complete. The next challenge for the Analysis team was to reduce this collection into a mutually exclusive and collectively exhaustive set. The affinity exercise proved to be an ideal method for this task aggregation.

The Affinity Exercise

An affinity exercise (also called an affinity diagram) is a method designed to allow a team of people to generate a topical list of ideas creatively and subsequently arrange those ideas into natural groupings. Once similar ideas are grouped together, the team assigns names or headers to each collection of ideas.[26] The affinity exercise is a simple yet potentially fruitful process. Besides fostering creativity by each participant, it "encourages nontraditional connections among ideas." Identifying these nontraditional connections among ideas, thus breaking free from contemporary biases, was the aim of the Analysis team. A final benefit of the affinity exercise is that it encourages mutual exclusivity because all similar tasks are grouped together and confined to a single location in the model.

The Analysis team applied this technique by combining the 109 tasks in figure 2-9 into logical groups. The result of this first affinity exercise was a set of 14 mutually exclusive, collectively exhaustive tasks (fig. 2-10). These 14 task groupings were collectively exhaustive because every one of the 109 tasks in figure 2-9 was gathered into one of the 14 groups. The 14 tasks represented by these groups are mutually exclusive because each of the boxes in figure 2-10 represents a fundamentally different activity. The initial tasks grouped inside the boxes, of course, represent fundamentally similar tasks.

Next, the Analysis team assigned a name to each of the groups. The group name came usually, but not always, from one of the initial tasks in the group. The ***Foundations 2025*** glossary (appendix A) formally defines the group names.

Distinguishing Subtasks from Tasks

The second affinity grouping determined which of the 14 tasks in figure 2-10 were truly tasks and which were lower-level subtasks. As figure 2-11 shows, six of the 14 tasks were grouped together under a broader task labeled *direct*, and two of the 14 were grouped into a broader task called *understand*. These subtasks were grouped together because, even though they represented different activities, they were closely related. The six tasks under direct—*assess, decide, plan, communicate, confirm,* and *educate/train*—became subtasks, as did *integrate* and *identify* under understand.

The Influence of the Medium on Certain Tasks

The ***2025*** white paper writing teams felt that some tasks in figure 2-11 were fundamentally different, depending on the medium in which the tasks take place. For example, to detect something in the air is fundamentally different from detecting something on the ground or in cyberspace. Likewise, to engage a target in space is a different task than to engage on the surface. Therefore, the Analysis team had to determine which of the eight tasks were affected by the medium, and, if so, divide those tasks into subtasks to ensure mutual exclusivity.

The four possible media were defined to be air, space, cyberspace, and surface/subsurface; therefore, under the task *detect*, there are four subtasks: *detect (things) in the air, detect in space, detect in cyberspace,* and *detect on the surface* (and *subsurface*). This same logic applied to the *engage, survive, deploy, maintain,* and *replenish* tasks. Note that the medium where the target (the thing being detected or engaged) is located, not where the system doing the detecting or engaging is located.

Three tasks in ***Foundations 2025*** were determined not to be medium specific: *understand, direct,* and *maintain.* To *understand* (*integrate* and *identify*) what was detected does not depend on where the

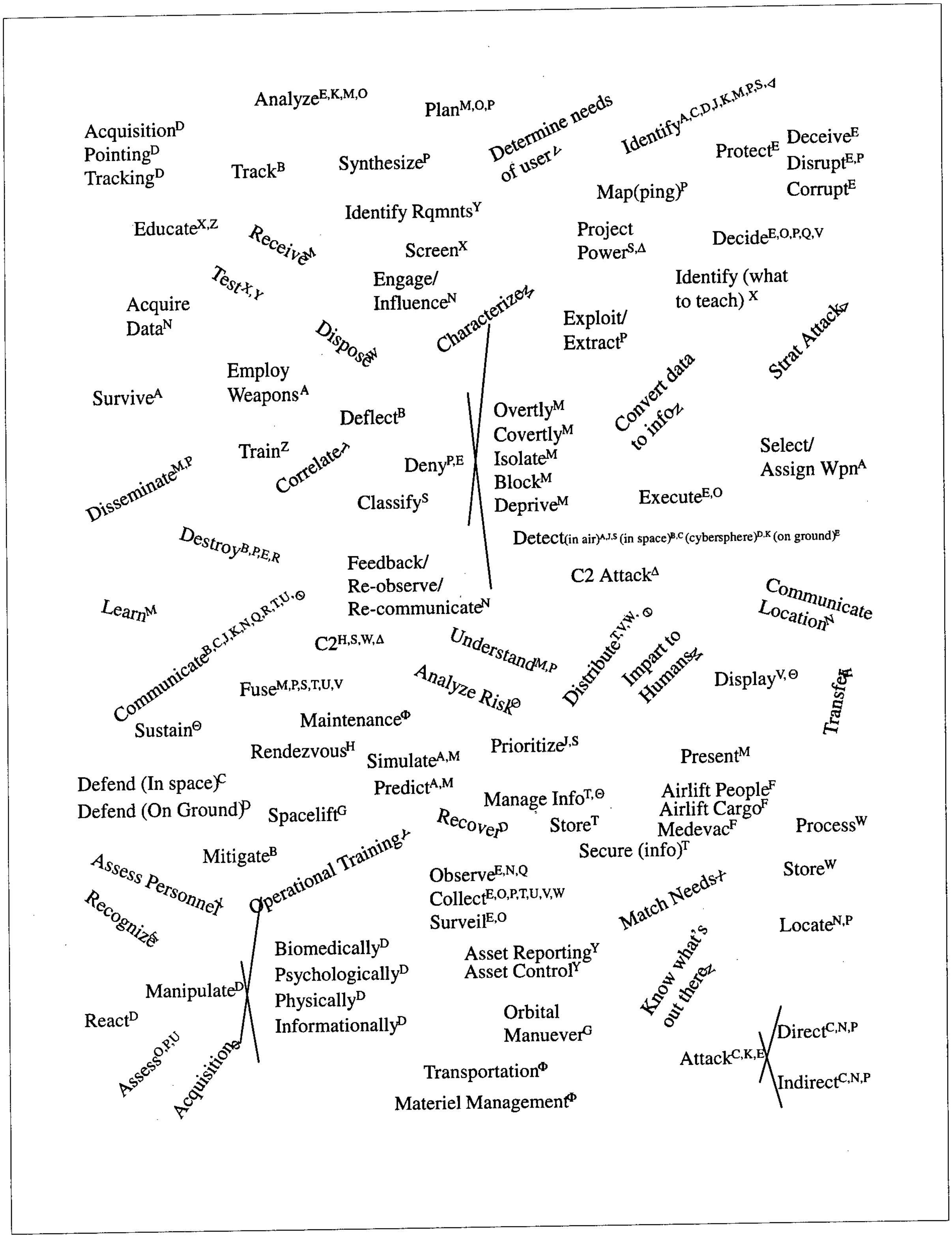

Figure 2-9. ***2025*** **Initial Task Compilation**

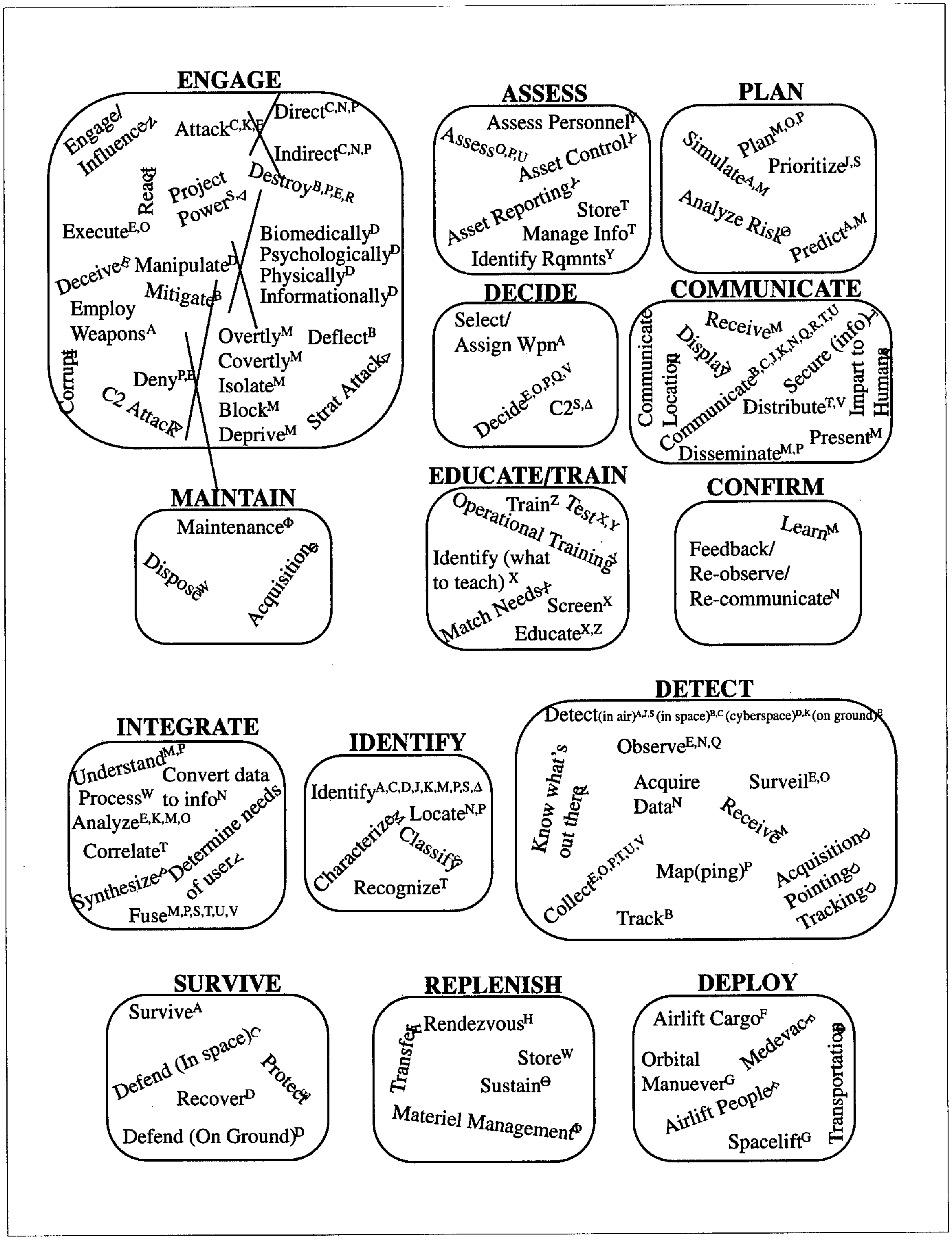

Figure 2-10. First Affinity Grouping of Tasks

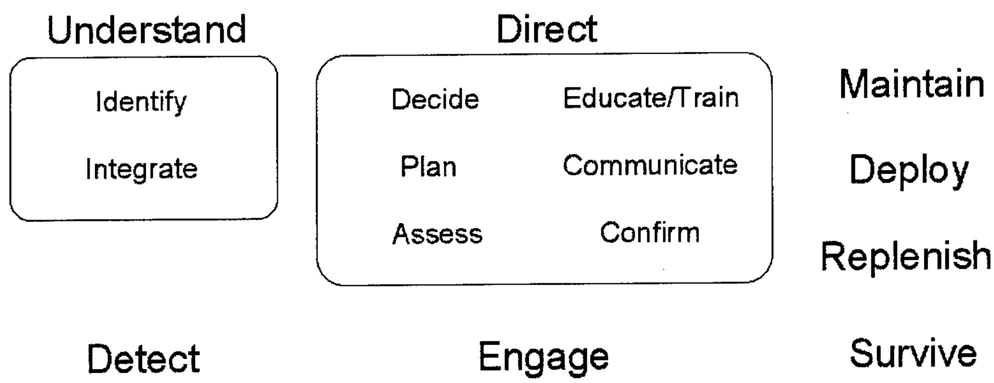

Figure 2-11. Second Affinity Grouping of Tasks

integrating and identifying occurs. Imagine a fusion center receiving data from sensors in the air, in space, and on the ground. The process of understanding the data passed to the fusion center is not affected by the location of the center. Likewise, the commander's ability to *direct*, including *assess*, *plan*, and *decide* is not affected by the medium in which these activities occur. Similarly, the ability to *maintain* is related to *readiness* and the ability to *sustain*, but not specifically to a medium.

Two points about the medium-specific subtasks warrant explanation. First, the notions of *deploy to air* and *replenish in air* seemed at first to be far-fetched or unnecessary. However, one of the proposed ***2025*** systems was an airship with the ability to loiter in the air for several days. ***Foundations 2025*** needed to be sufficiently robust to evaluate such systems and forward thinking in establishing the value of these futuristic tasks.

Second, there were no subtasks in the cyberspace medium for the *deploy*, *maintain*, and *replenish* tasks. In this paper, cyberspace is defined as "the *virtual* [emphasis added] space of computer memory and networks, telecommunications, and digital media."[27] Because cyberspace is a virtual space, there is no need to move or deploy. The Internet is a good example; being on-line means being engaged.

A medium-specific distinction does not imply that a particular system cannot perform in different media. By dividing some tasks into subtasks based on medium, distinct system capabilities were evaluated based on the phenomenology associated with the medium. In the ***Foundations 2025*** value model, a satellite that can detect targets on the surface, in the air, and in space received credit for performing three distinct subtasks.

Adding medium-specific subtasks increased the number of subtasks in the model from eight to 29. Figure 2-12 shows the complete list of tasks and subtasks, including medium-specific subtasks. The next step in the hierarchical evolution of the value model was to generate functions.

Functions

Functions are the high-level, aggregated tasks that must be accomplished to attain the overarching objective of *air and space dominance*. Three functions for the future Air Force emerged from the third and final affinity grouping: *awareness*, *reach*, and *power*. *Awareness* is specified by the tasks *detect*, *understand*, and *direct*. To have *reach* requires the ability to *deploy*, *maintain*, and *replenish*. *Power* comes from the ability to *engage* and *survive*. The Analysis team adopted the following definitions for these three functions:

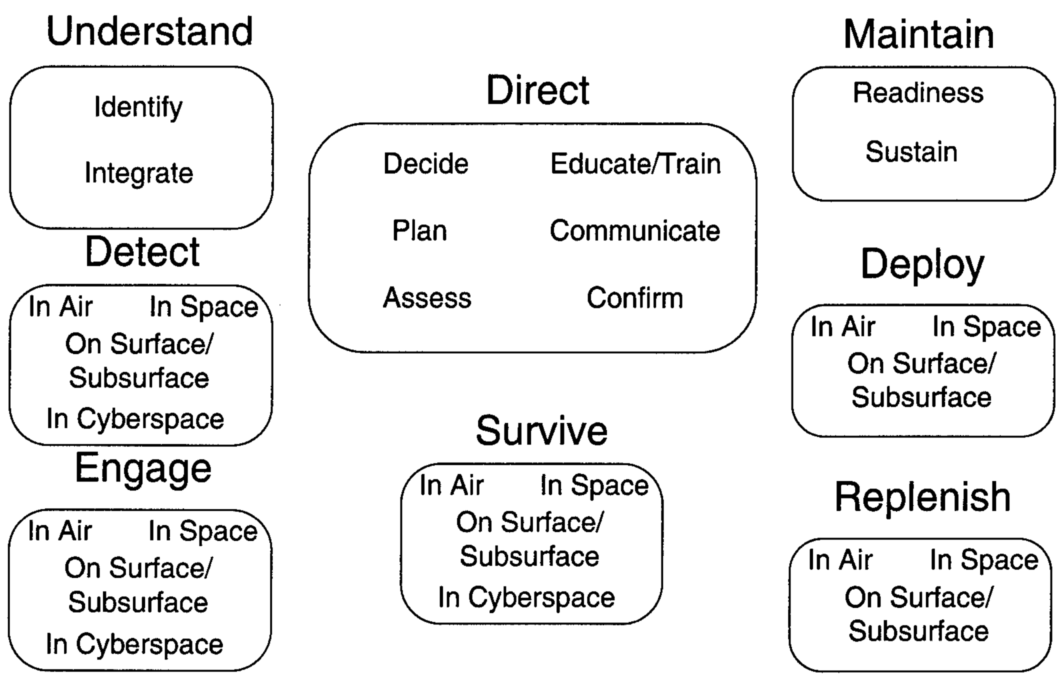

Figure 2-12. Inclusive Grouping of Tasks and Subtasks

- *Awareness*—knowledge, understanding, or cognizance of some thing or situation through alertness in observing, detecting, and identifying, so as to enable, direct, and communicate an informed decision.
- *Reach*—ability to move to expand the range or scope of influence or effect, and to sustain this influence or effect by maintaining and replenishing.
- *Power*—ability to overtly or covertly affect, control, manipulate, deny, exploit, or destroy targets, including forces, people, equipment, and information, and the ability to survive while affecting targets.

These definitions are based on the tasks in the affinity diagrams upon which the functions were built (fig. 2-10), and they suggest that the critical functions of air and space forces in the future do not differ significantly from the functions of today. Where the future begins to diverge from the present is in the detailed means (i.e., tasks and subtasks) by which these functions are accomplished.

Two critical implications appear when the requirement for a set of functions in a value model are mutually exclusive and collectively exhaustive. First, these three ***2025*** functions should encompass *every* future air and space force operational activity. Second, *awareness*, *reach*, and *power* are the only operational activities that contribute to the overarching objective of air and space dominance.

Once the functions were developed, the bottom-up evolution of the subtasks, tasks, and functions in the ***Foundations 2025*** value model was complete. Figure 2-13 depicts the entire framework of mutually exclusive and collectively exhaustive functions, tasks, and subtasks to be accomplished by future air and space forces. Next, force qualities, measures of merit, and scoring functions had to be added to the framework to finalize the model.

Force Qualities

Though the framework shown in figure 2-13 represented a major breakthrough, it was not a complete value model. The next step for the Analysis team was to meet with each of the ***2025*** white paper writing teams for a second time to determine force qualities, based on the teams' operational expertise, research, and thoughts about the future. Force qualities are generally adjectives, since they characterize a system's ability to accomplish a task or subtask. In many cases, the desired force qualities of a future force did not differ from qualities expected of today's force. For example, the force qualities associated with the subtask *identify* were *accurate*, *timely*, and *traceable*. The goal was to identify only the most important force qualities for each subtask.

Some common themes emerged in the force quality development process. For almost every subtask, *timely* was a desired force quality. *Unobtrusive* was another commonly occurring force quality; it is listed under every *detect* and *engage* subtask. Clearly, the ability to watch without being watched, and act without being observed, are desirable qualities of future air and space forces. Lastly, most of the writing teams felt that flexibility was important across the spectrum of tasks. Several force qualities address flexibility: *multirole*, *reusable platform*, *desired lethality*, and *sensor variety*.

These force qualities and measures of merit were continually refined during a succession of meetings. After working with each ***2025*** white paper writing team, the Analysis team reduced the list of force qualities from the initial number of about 1,200 to the final number of 134. There are approximately five force qualities for each subtask. The largest number of subtask force qualities was nine, the fewest was two. Figures 2-14 through 2-16 show the final force qualities for ***Foundations 2025***, organized under the functional categories of *awareness*, *reach*, and *power*.

Measures of Merit and Scoring Functions

Corresponding measures of merit were developed at the same time the Analysis team met with the ***2025*** writing teams to determine force qualities. Each force quality had a measure of merit to calibrate system performance. For example, a force quality of the subtask *deploy to air* was *range*, and the corresponding measure of merit was *miles*. The measures of merit became the domains (horizontal axis) of the scoring functions used to evaluate the capabilities of future systems.

The Analysis team again worked closely with the ***2025*** writing teams to build the scoring functions associated with the teams' respective portions of the value model. The result—134 detailed functions that quantify operational values—represent an important analytical accomplishment. They span the spectrum of air and space operations, and, as such, serve as a wealth of information for mission area analysts and weapon system developers. Appendix A contains the complete set of the Air Force ***2025*** measures of merit and scoring functions.

Foundations 2025 represents five important analytic advances. First, the collection of scoring functions serves as an invaluable resource, even outside the ***2025*** study. Second, the use of verbs to specify tasks was a useful step in the value model evolution. Third, the bottom-up approach used in developing ***Foundations 2025*** was significant because no *a priori* assumptions were made and no preconditions were established. Building from the bottom up allowed ***Foundations 2025*** to be free from institutional bias, an outcome necessary to capture the visionary thinking of ***2025***. Fourth, ***Foundations 2025*** is a robust value model. With five tiers consisting of an overarching objective, three functions, eight tasks, 29 subtasks, and 134 force qualities (each with a corresponding measure of merit and scoring function)—and all weighted across six alternate futures—the model can be used to evaluate diverse systems. Finally, ***Foundations 2025*** is cast further into the

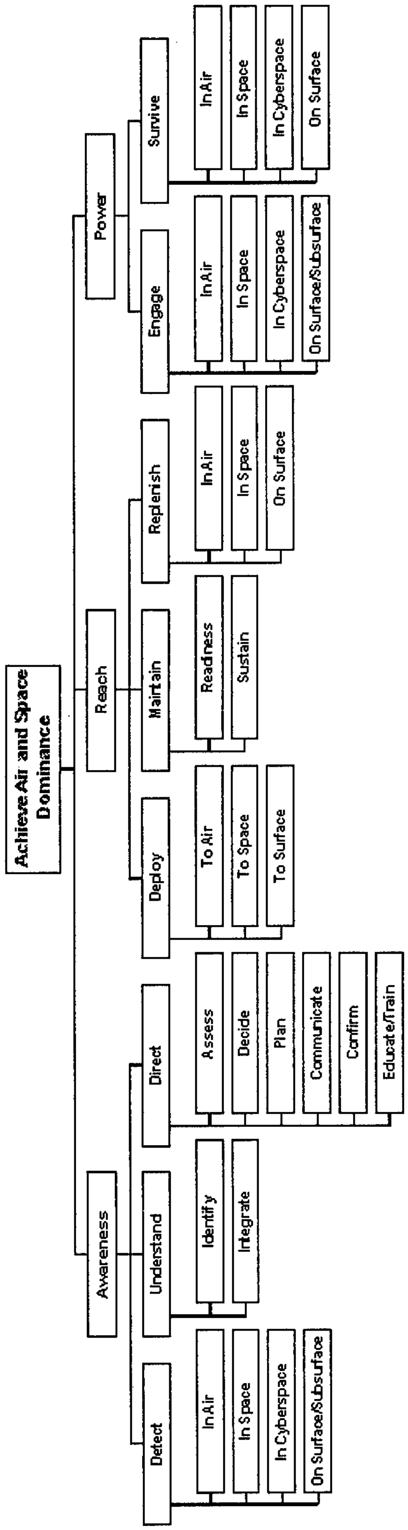

Figure 2-13. *Foundations 2025* Value Model

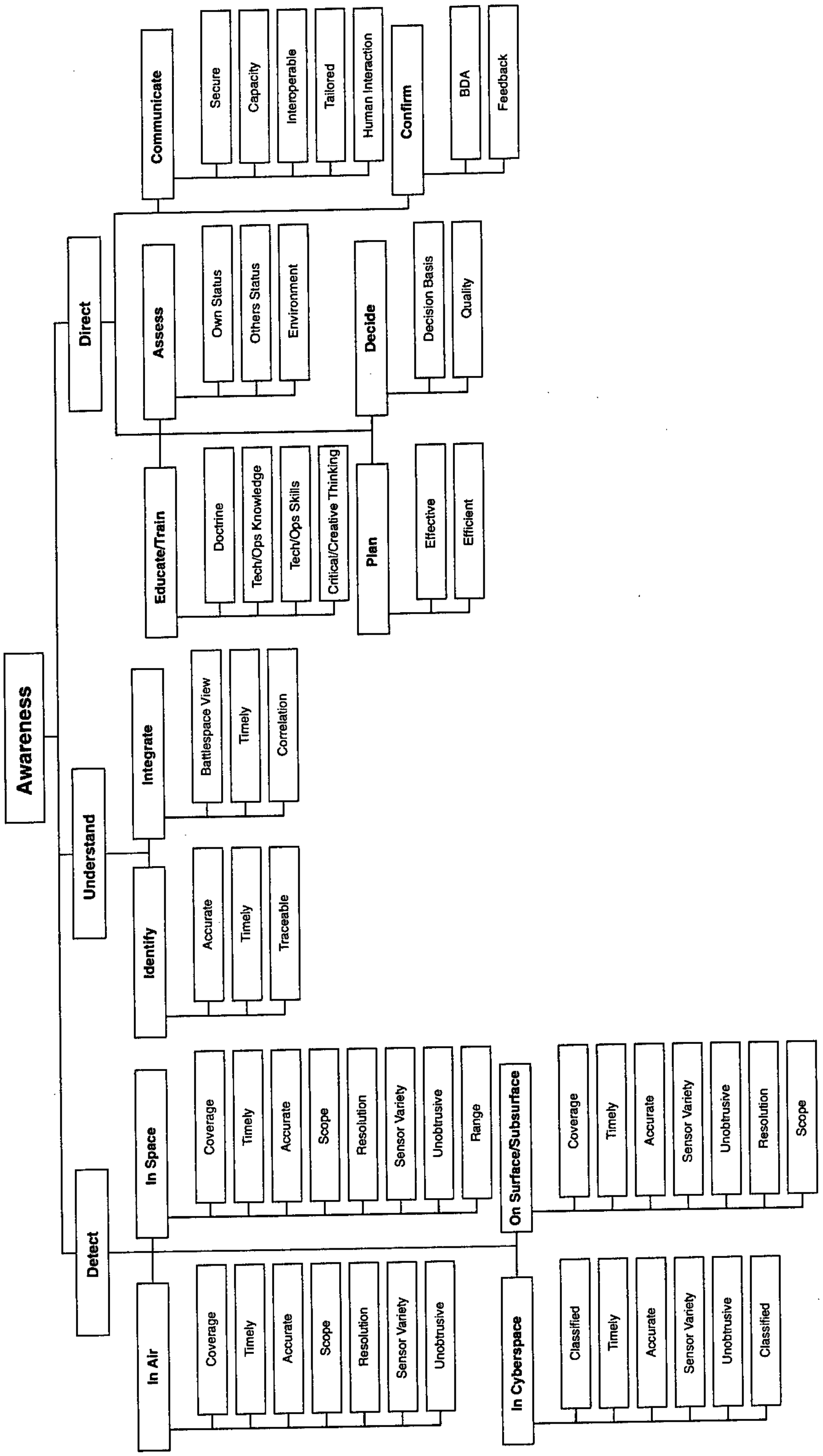

Figure 2-14. *Awareness* Tasks, Subtasks, and Force Qualities

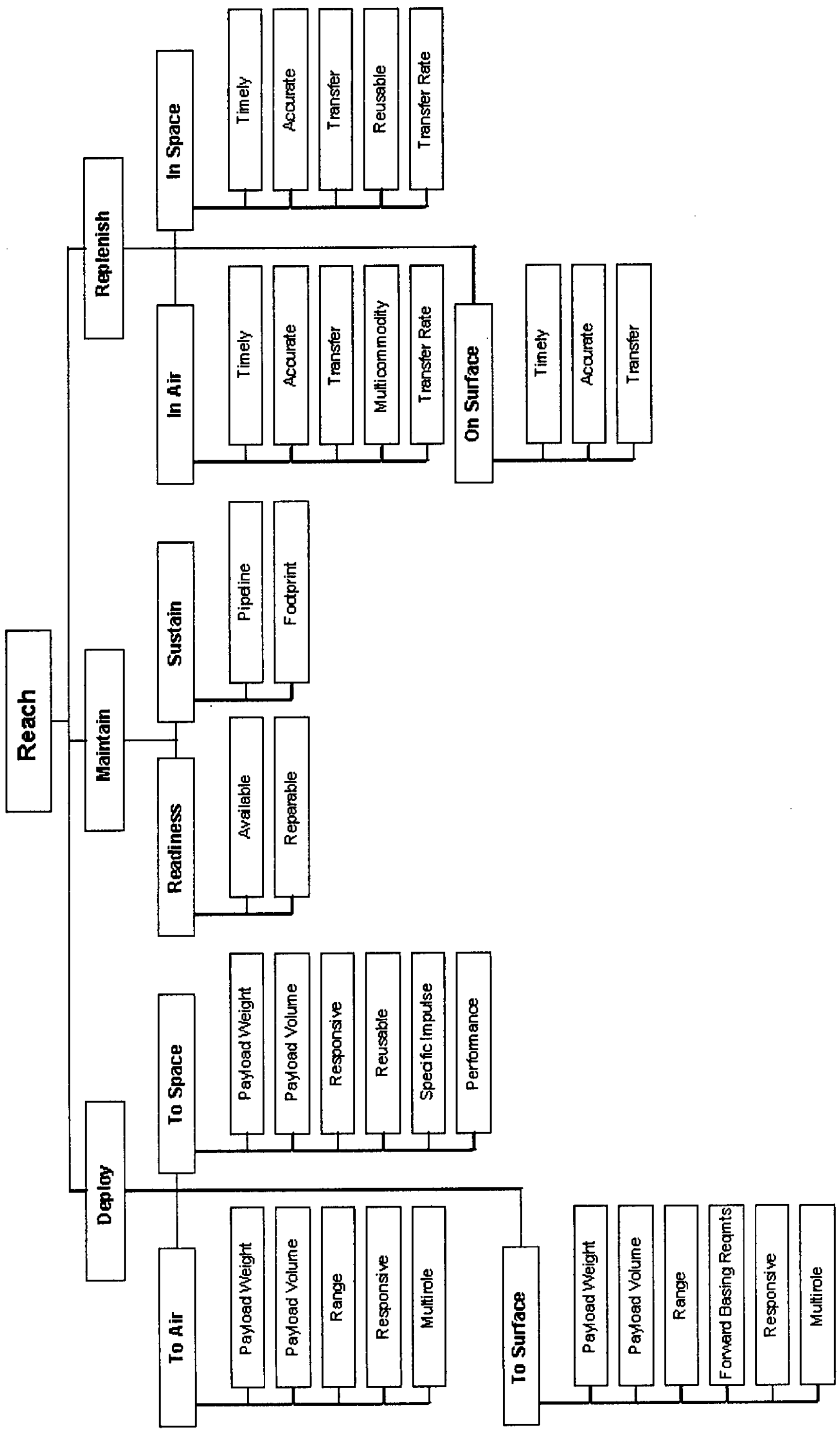

Figure 2-15. *Reach* Tasks, Subtasks, and Force Qualities

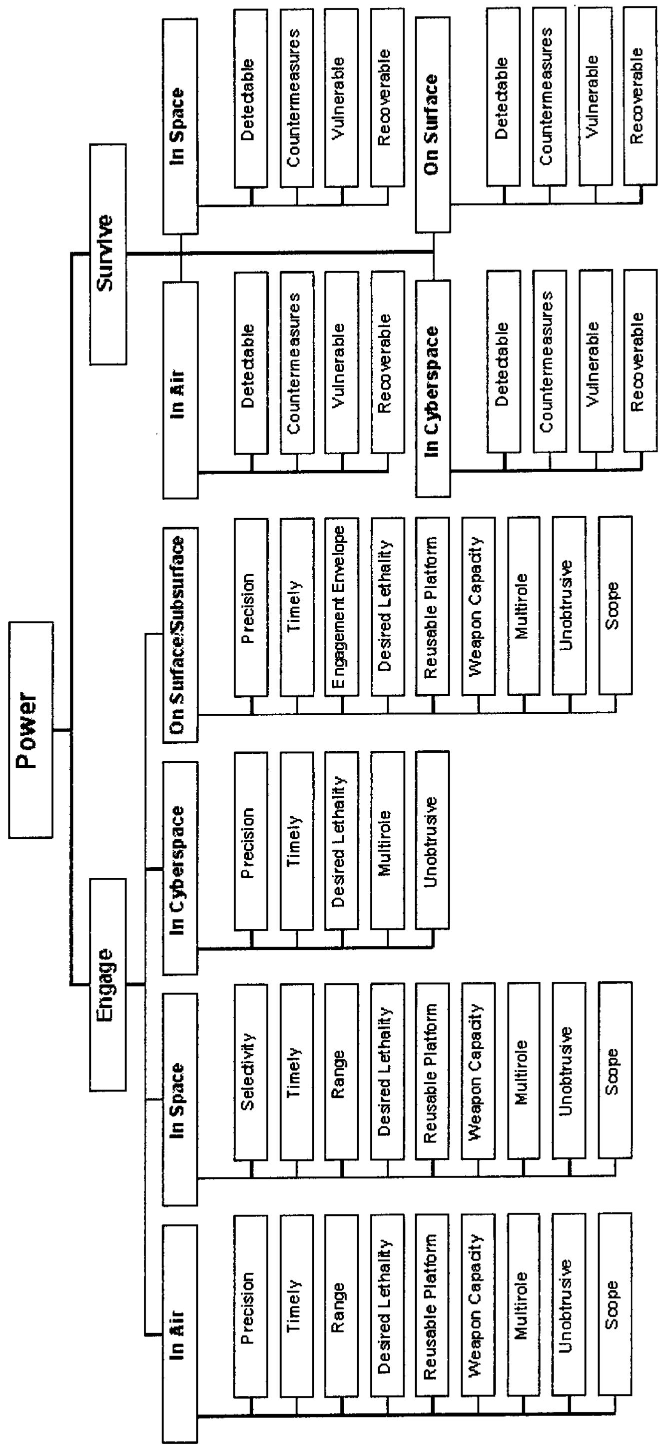

Figure 2-16. *Power* Tasks, Subtasks, and Force Qualities

future than any other known military value model.

After the ***Foundations 2025*** development was completed, the next step in the ***2025*** OA was to use the model to evaluate systems. The ***2025*** white papers provided the key information for identification and definition of the systems.

System Identification

Following a thorough review of the ***2025*** white papers, the Analysis team identified 43 unique high-leverage systems. For this operational analysis, a system was defined to be "a functionally related group of elements that performs a mission or task." Although some of the identified systems were extracted from a single white paper, many systems, particularly those involving the collection and management of information, were composites drawn from capabilities detailed in several of the papers. For example, the use of a "personal digital assistant" was a key element of 10 white papers on issues ranging from special operations to general education and training. In several of the papers, such as the one entitled "A Contrarian View of Strategic Aerospace Warfare," no systems could be identified. In these cases, the papers contained a general framework for doing business in given mission areas without a level of detail required for technology identification.

The 43 systems are listed in table 1, categorized by the major functional areas depicted in figure 2-17. The full descriptions of these systems are found in appendix B.

Alternate Futures

The ***2025*** Alternate Futures team generated and then analyzed more than 100 candidate drivers deemed to be forces acting on the future. These drivers were then synthesized and consolidated into the three most important drivers to define a strategic planning space in which alternate futures could be cast (fig. 2-18). Functional definitions for each of these three drivers are provided below:

- **American Worldview**—This driver is the US perspective of the world which determines the willingness and capability to interact with the rest of the world. American worldview captures the dominant US focus regarding international affairs. The US can be primarily internally focused, perhaps even isolationist, or the US can be actively engaged in activities around the world. The poles of American worldview are domestic and global.
- **ΔTeK**—This driver is the differential in the rate growth, proliferation, leverage, and vitality of scientific knowledge and technical applications and their consequences. ΔTeK describes the rate of change in both the proliferation and advancement of technology. The two poles of ΔTeK are constrained and exponential. Constrained ΔTeK implies technology is advancing at an evolutionary rate and its availability is limited to a relatively few number of actors. Exponential ΔTeK occurs when there are revolutionary breakthroughs in technology that are rapidly proliferate throughout the world.
- **World Power Grid**—This driver describes the generation, transmission, distribution, and control of power throughout the world. This power is a combination of economic, political, and information sources of power as well as military strength. The two poles of this driver are concentrated and dispersed. A concentrated world power grid exists when few actors have the means or will to influence others. When a myriad of groups or individuals can change the future, the World Power Grid is dispersed.

Six alternate futures were chosen from this planning space to provide a diverse set of future conditions against which to evaluate the proposed air and space systems. Four futures are extremes: Gulliver's Travails,

TABLE 1

IDENTIFIED SYSTEMS

1.0	Vehicles - Air Only (Piloted) 1.1 Hypersonic Attack Aircraft 1.2 Fotofighter 1.3 Container Aircraft 1.4 Lighter-than-Air Airlifter 1.5 Supersonic Airlifter 1.6 Stealth Airlifter 1.7 Global Transport Aircraft
2.0	Vehicles - Air Only (Uninhabited) 2.1 Strike UAV 2.2 Reconnaissance UAV 2.3 Uninhabited Combat Air Vehicle 2.4 Precision Delivery System 2.5 UAV Mothership 2.6 Exfiltration Rocket
3.0	Vehicles - Space Only 3.1 Orbital Maneuvering Vehicle 3.2 Orbital Combat Vehicle 3.3 Satellite Bodyguards
4.0	Vehicles - Air and Space 4.1 Piloted SSTO Transatmospheric Vehicle 4.2 Uninhabited Air-Launched Transatmospheric Vehicle
5.0	Weapons - Air and Ground-Based 5.1 Adjustable Yield Munition 5.2 Advanced Air-to-Air Missile 5.3 Airborne High-Power Microwave Weapon 5.4 Standoff Hypersonic Missile 5.5 Attack Microbots 5.6 Airborne Holographic Projector 5.7 Hybrid High-Energy Laser System
6.0	Weapons - Space-Based 6.1 Global Area Strike System 6.2 Space-Based Kinetic Energy Weapon 6.3 Space-Based High-Power Microwave Weapon 6.4 Space-Based High-Energy Laser 6.5 Solar-Powered High-Energy Laser System 6.6 Solar Energy Optical Weapon 6.7 Asteroid Mitigation System
7.0	Information Systems - Individual 7.1 Spoken Language Translator 7.2 Personal Digital Assistant 7.3 Virtual Interaction Center
8.0	Information Systems - Global 8.1 Global Information Management System 8.2 Global Surveillance, Reconnaissance, and Targeting System 8.3 Sensor Microbots 8.4 Multiband Laser Sensor System 8.5 Asteroid Detection System
9.0	Miscellaneous Systems 9.1 Mobile Asset Repair Station 9.2 Weather Analysis and Modification System 9.3 Sanctuary Base

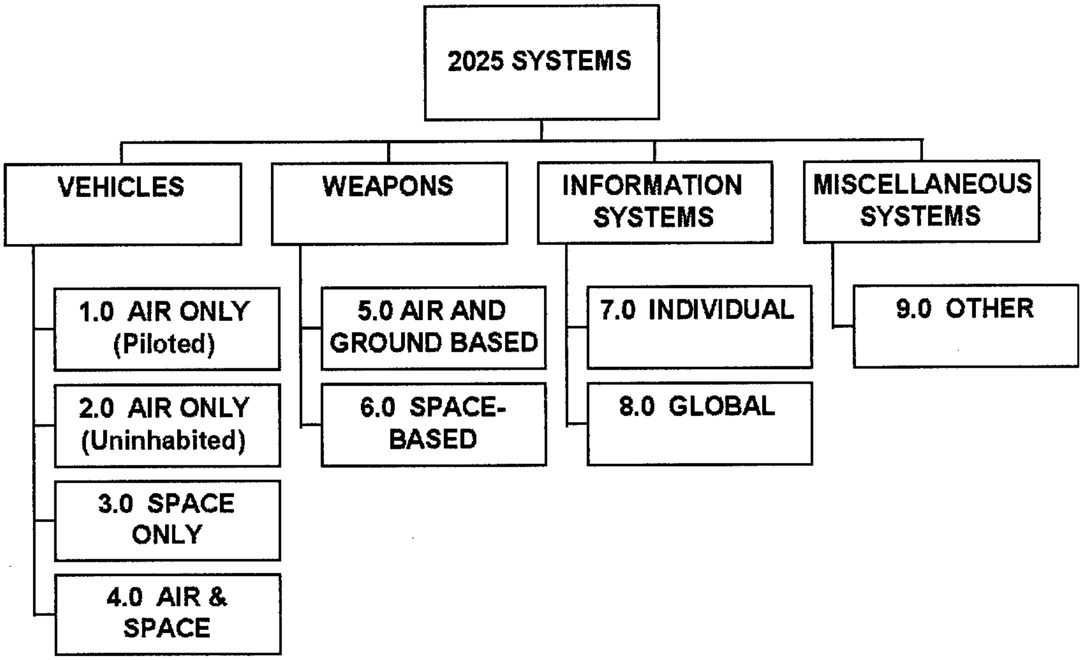

Figure 2-17. System Functional Hierarchy

Zaibatsu, Digital Cacophony, and King Khan. The world of Halfs and Half-Naughts was chosen for its centrality. Finally, the *2015 Crossroads* future provides a conservative bridge between today and 2025.

In Gulliver's Travails, the US is overwhelmed with worldwide commitments, counterterrorism and counterproliferation efforts, humanitarian operations, and peacekeeping operations. In Zaibatsu, multinational corporations dominate international affairs, loosely cooperating to create a relatively benign world. Digital Cacophony is the most technologically advanced world resulting in great power and independence for the individual but also creating a world of social isolation, fear, and anxiety. King Khan is a world where US dominance has waned due to domestic problems, an economic depression, and overshadowing by a rising Asian colossus. The world of Halfs and Half-Naughts is dominated by conflict between the "haves" and "have-nots" and dynamically changing social structures and security conditions. *2015 Crossroads* uses programmed forces from 1996–2001 to fight a major conflict; it presents the US with a strategic challenge in 2015 that could lead to any of other alternate futures by 2025.

These six alternate futures provided the fulcrum against which the ***2025*** Operational Analysis was applied to determine which of the many systems proposed by the study participants had merit and, hence, should be pursued by the United States Air Force to ensure air and space dominance in the future.

Scoring the Systems

This section describes how ***Foundations 2025*** was used to evaluate future air and space systems. The process had two steps. The first step assigns weights to the model hierarchy, and the second computes performance scores using scoring functions. The scoring in this section provides the reader with an example of the score computation process; the results of the

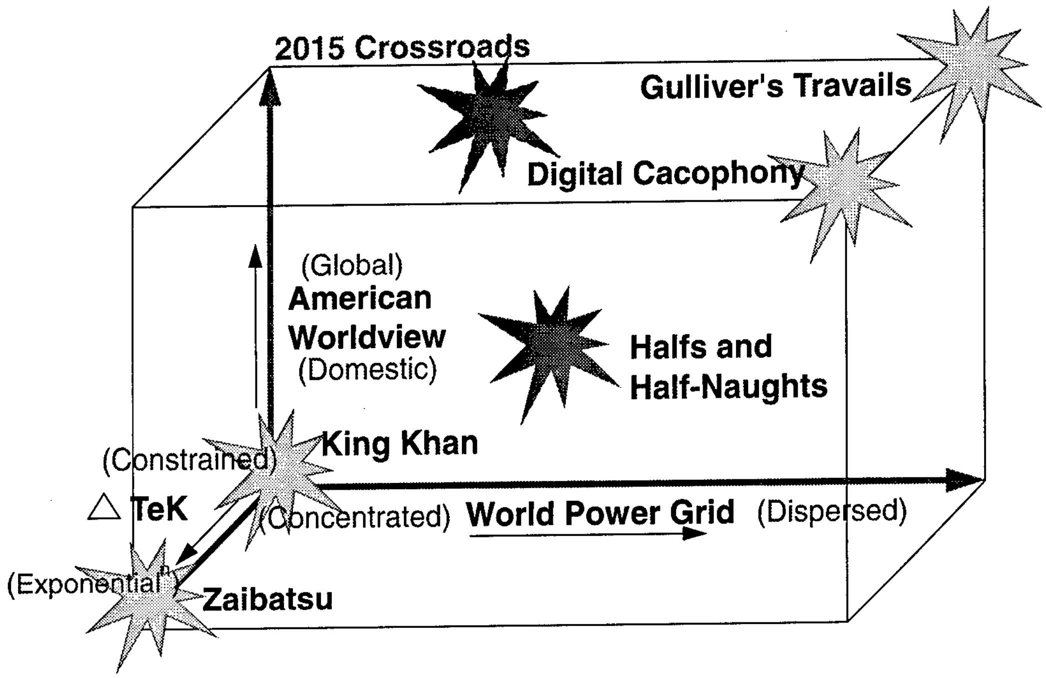

Figure 2-18. Alternate Futures Planning Space

actual ***2025*** systems evaluation are described in chapter 3.

Weighting the *Foundations 2025* Value Model across Alternate Futures

The first step in using the 2025 value model is for the decision maker to determine the relative importance of the functions, tasks, subtasks, and force qualities. As described in the previous section, the decision maker weights functions, tasks, subtasks, and force qualities. Because different futures dictate a different set of required air and space capabilities, the Analysis team obtained value model weights from the ***2025*** participants for the range of potential future worlds postulated by the ***2025*** Alternate Futures team. For each alternate future, the Analysis team used two sets of weights. The first, denoted "AU Team Weights," is an average of the weights assigned by student members of the ***2025*** white paper writing teams. The second, denoted "Alt Futures Weights," is the weights provided solely by the Alternate Futures team. In general, the Alternate Futures Weights exhibited greater variation across futures than did the AU Team Weights. Weights were held constant for the force qualities and measures of merit because they were not expected to vary much across possible futures. The weights for each future are contained in appendix C.

Technology Identification and Scoring

Once the 43 unique systems contained in the white papers were identified, the Analysis team qualitatively analyzed each system to identify which technology areas would be key to achieving the stated system capabilities. Only those technology areas needing development were considered. For example, if a specific technology area was critical to a given system's capability, but no

new advances were needed in this area for the system to achieve its full capability, then this technology area was not identified as high leverage for this particular system.

The team felt that it was highly desirable to identify and group technologies according to a well-known "gold-standard." Thus, the DOD document, *The Militarily Critical Technologies List* (MCTL), was used as the basis for key technology identification in each system. For the 43 systems evaluated, a total of 43 key technology areas were identified. Full descriptions of each technology area, as paraphrased from the MCTL, can be found in appendix D.

To eventually rank technologies by their impact on future air and space capabilities, the team assigned a relative weight to each technology embedded in a particular system. The weights selected sum to 100 for each system and so can be thought of as percentages of the system's dependence on each technology needing development. For example, the five piloted single-stage-to-orbit (SSTO) transatmospheric vehicle (TAV) technologies were weighted as follows:

Technology Area	Weight
Aerospace Structures and Systems	25
High-Energy Propellants	25
RAMjet, SCRAMjet, Combined Cycle Engines	20
Advanced Materials	20
High-Performance Computing	10

In this case, since the primary mission of the piloted SSTO TAV is to travel between the surface and low-earth orbit, the highest leverage technology areas were those of the vehicle's primary propulsion and structural subsystems. Each of these areas was evaluated to be essentially equal in importance. The fifth technology area, high-performance computing, was added not necessarily because of vehicle requirements, but because the design process for this type of vehicle will take some advances in computing power. Without advances in high-performance computing, the design process for a TAV with this capability would be impaired. This methodology makes it possible to score each of the systems.

Once the system-versus-technology matrix is developed, the procedure for scoring the technologies is straightforward. The contribution of technology to each system is multiplied by the system value, and the resulting products are summed across all systems. The result is a set of technology scores (normalized to a maximum score of 100) that takes into account both the technologies' degree of contribution to future air and space systems and the importance of those systems to air and space operations. This scoring was then repeated for each alternate future since the system values changed with each future.

After each technology area had been identified, one additional question remained, "Who, the DOD or the commercial sector, is the key player in developing each of the 43 technology areas?" AFIT's Graduate School of Engineering assembled a committee from its senior staff to consider this question. This committee qualitatively evaluated each technology area to determine the appropriate key developer. They further ascertained the direction of each developmental effort, whether from the DOD to the commercial sector, from the commercial sector to the DOD, or remaining constant.

Notes

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3. Keeney, 3.
4. Ibid., 6.
5. Ibid., 7.
6. Ibid., 33.
7. Ibid., 112.
8. R. T. Clemen, *Making Hard Decisions: An Introduction to Decision Analysis* (Boston, Mass.: PWS-Kent, 1991).
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12. Ibid.
13. Clemen, 435.
14. Ibid., 435–36.
15. Keeney, 129–54.

16. Clemen, 435–36.

17. *A National Security Strategy of Engagement and Enlargement* (Washington, D. C.: The White House, February 1995).

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Chapter 3

Results

A team of technical and operational experts, the Analysis team, scored all 43 systems against each metric in ***Foundations 2025***. The team followed a consensus-seeking approach to obtain each score. The team was not permitted to know the shape of the scoring function and was tasked to place a score for each metric along the horizontal axis of each function shown in figures A-5 through A-32 for each system. The analysis was performed using Logical Decisions for Windows© software running on a Pentium-based PC.

The results of the system scoring are summarized in figure 3-2 through figure 3-6. The vertical axis is the score from the system evaluation on a scale of 0 to 100, where a system score of zero equates to no score on any of the 134 scoring functions. The horizontal axis is a rank ordering of the systems according to the Analysis team's assessment of the relative amount of technical challenge to develop each system. The system scores are shown for two separate sets of weights—the AU Team Weights and the Alternate Futures Weights—for all six of the alternate futures. (figure 3-2 and figure 3-3)

Each system's scores for the various futures are plotted and connected with a line to show the variation of that system's score across the alternate futures. The resulting spread of scores for each system can be regarded as similar to error bars in the results of a statistical sampling technique. In other words, a system's score can be said with high confidence to lie within the range of the points shown. The curved dashed line provides a further reference for comparing systems. In the Analysis team's estimation, systems above the line may have sufficient value to offset the technical challenge of producing such a system. Thus, systems to the left of the charts need less value to be attractive options than systems to the right of the chart, because the difficulty of achieving the capability is much less. The exact location of the line is somewhat arbitrary. It was drawn fairly low, terminating on the right at a value of 20, to identify the most promising systems. (Note: A score of 10–15 may be good for some tasks.)

The highest value systems evaluated in this study are the Global Information Management System (GIMS), Sanctuary Base, Global Area Strike System (GLASS), Global Surveillance and Reconnaissance System (GSRT), and Uninhabited Combat Air Vehicle (UCAV). GIMS has the highest score but has high technical challenge, while GSRT performs some of the functions of GIMS but also with less technical challenge. Because of this, GSRT could be considered a "stepping stone" to GIMS. Both GLASS and UCAV score well because of a strong awareness component to complement their power contributions, and UCAV is the most feasible of all the high-value systems in the near term. Sanctuary base has high value but also the highest technical challenge. It may remain infeasible even beyond ***2025***. Appendix E contains tables of each system's value score for each future and weight set.

Dividing the figures above into quadrants provides a delineation of the systems into four categories based on value and technical challenge. Figure 3-1 shows representative systems for each quadrant.

Figure 3-4 and figure 3-5 provide a closer look at the highest scoring systems. Limiting the systems displayed to the top 25 percent (11 systems) for the AU Team Weights yields figure 3-4. A comparison of figure 3-4 and figure 3-5 reveals little

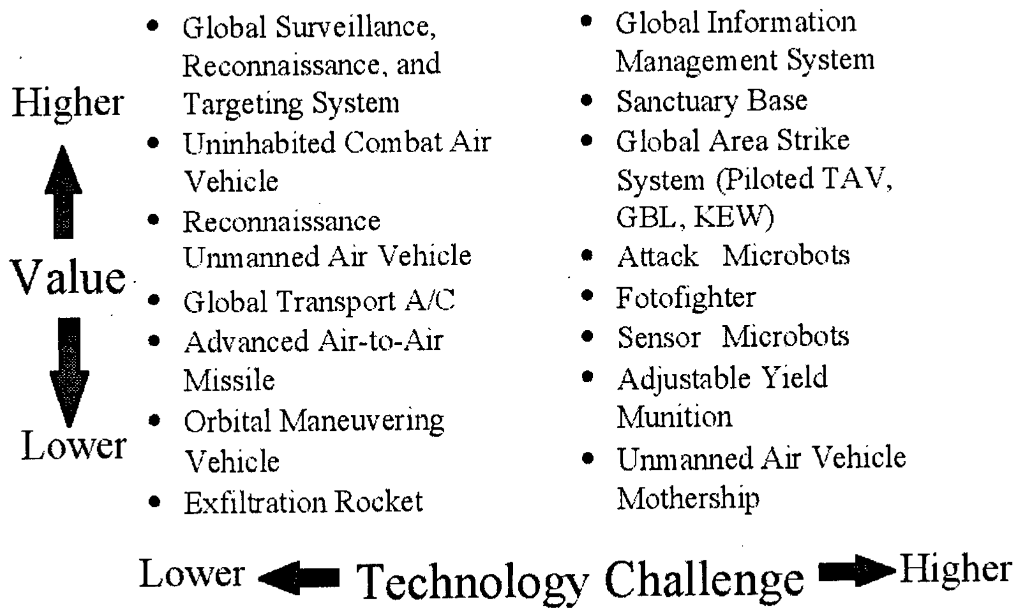


Figure 3-1. Representative Systems

difference between the overall scores and rankings for the AU Team Weights and the Alternate Futures Weights. The variation between futures is greater for the Alternate Futures Weights, reflecting both the more extreme views of a team immersed in the construction of the alternate futures and the centering effect of averaging the weights of the AU team members. However, the top 11 systems for the AU Team Weights are contained in the top 14 systems for the Alternate Futures Weights, with the Hypersonic Attack Aircraft, Fotofighter, and Sensor Microbots rounding out the 14 systems.

Figure 3-6 shows the relative contribution of the awareness, reach, and power sub-scores to the top 11 systems' scores using the AU Team Weights for the "Halfs and Half Naughts" alternate futures.

It is interesting to note the relationship between the *awareness, reach, and power* contributions to a system's score and the score variation between alternate futures. Systems that score similarly in *awareness, reach, and power* (e.g., GLASS in figure 3-6) tend to have the least variation; that is, the line connecting their scores for each future is short. This is because the weighted average of *awareness, reach, and power* (the overall score) is insensitive to changes in the weights when the *awareness, reach, and power* scores are of the same magnitude.

The scoring results highlight that a complex system (a system of systems) outscores any of its components. This is because of the additive nature of the scoring functions. The complex system scores more broadly since it contains the capabilities of its components, so it exceeds the score of any single component. Conversely, since component systems are unlikely to score in mutually exclusive areas of the value model, the complex system generally will score less than the simple sum of the component system scores.

Finally, figure 3-7 through figure 3-9 contain graphs similar to those in figure 3-2 and figure 3-3, but for the *awareness* function, the *deploy* task of *reach*, and the *power* function, respectively, using the AU Team Weights. These figures allow the reader to note the systems which score well for a particular function. For example, figure 3-7

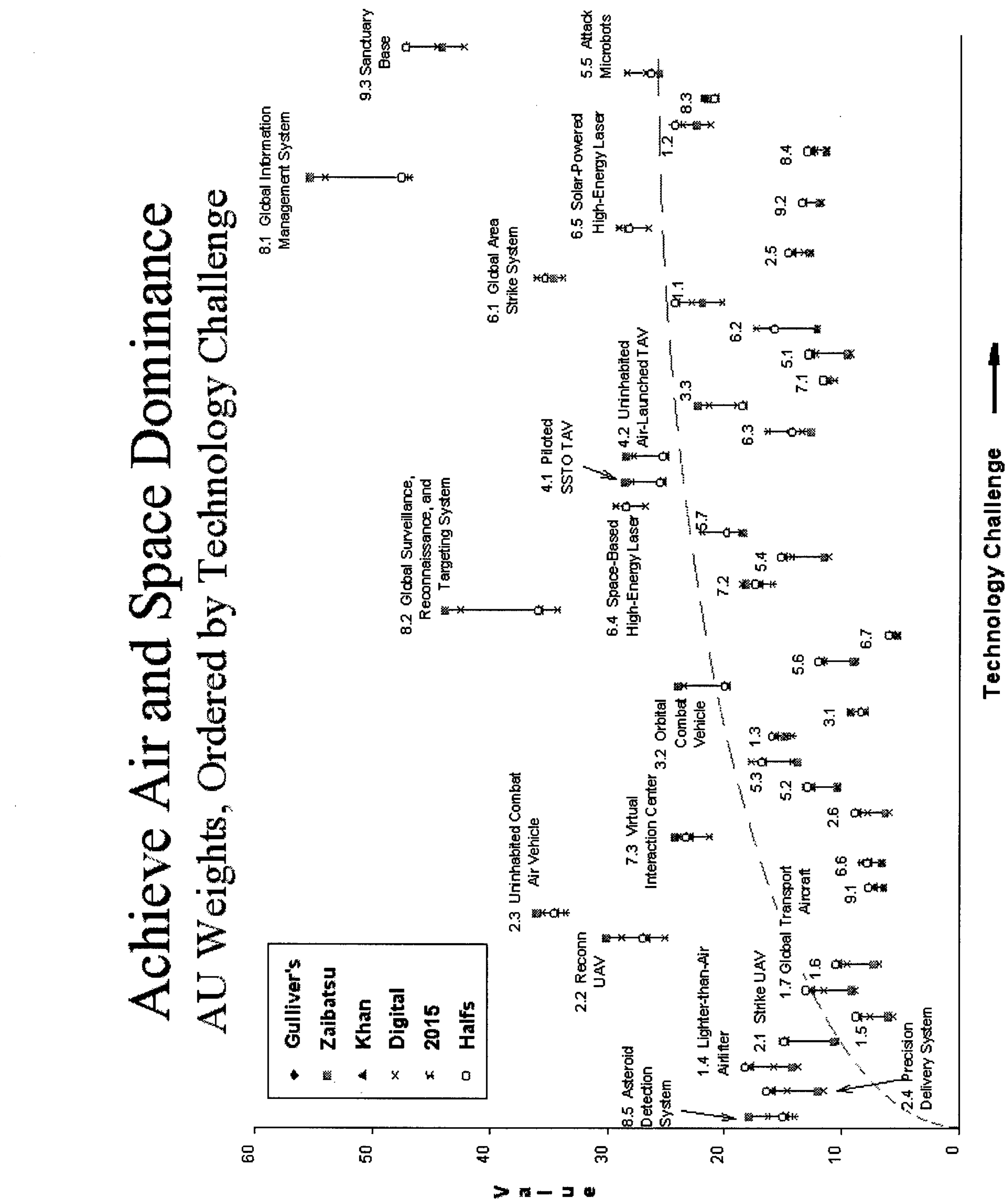


Figure 3-2. Final System Scores—AU Team Weights

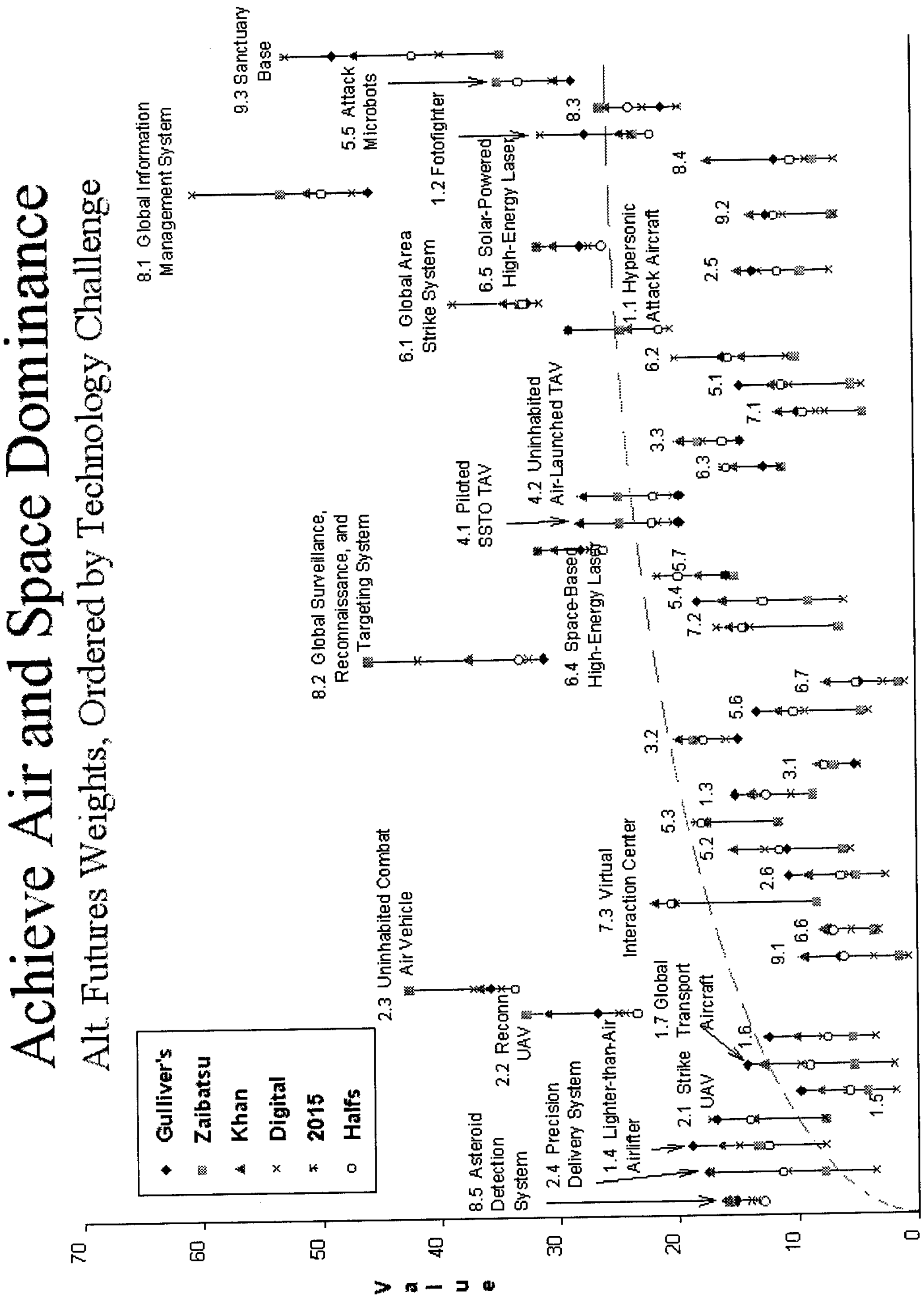


Figure 3-3. Final System Scores—Alternate Futures Weights

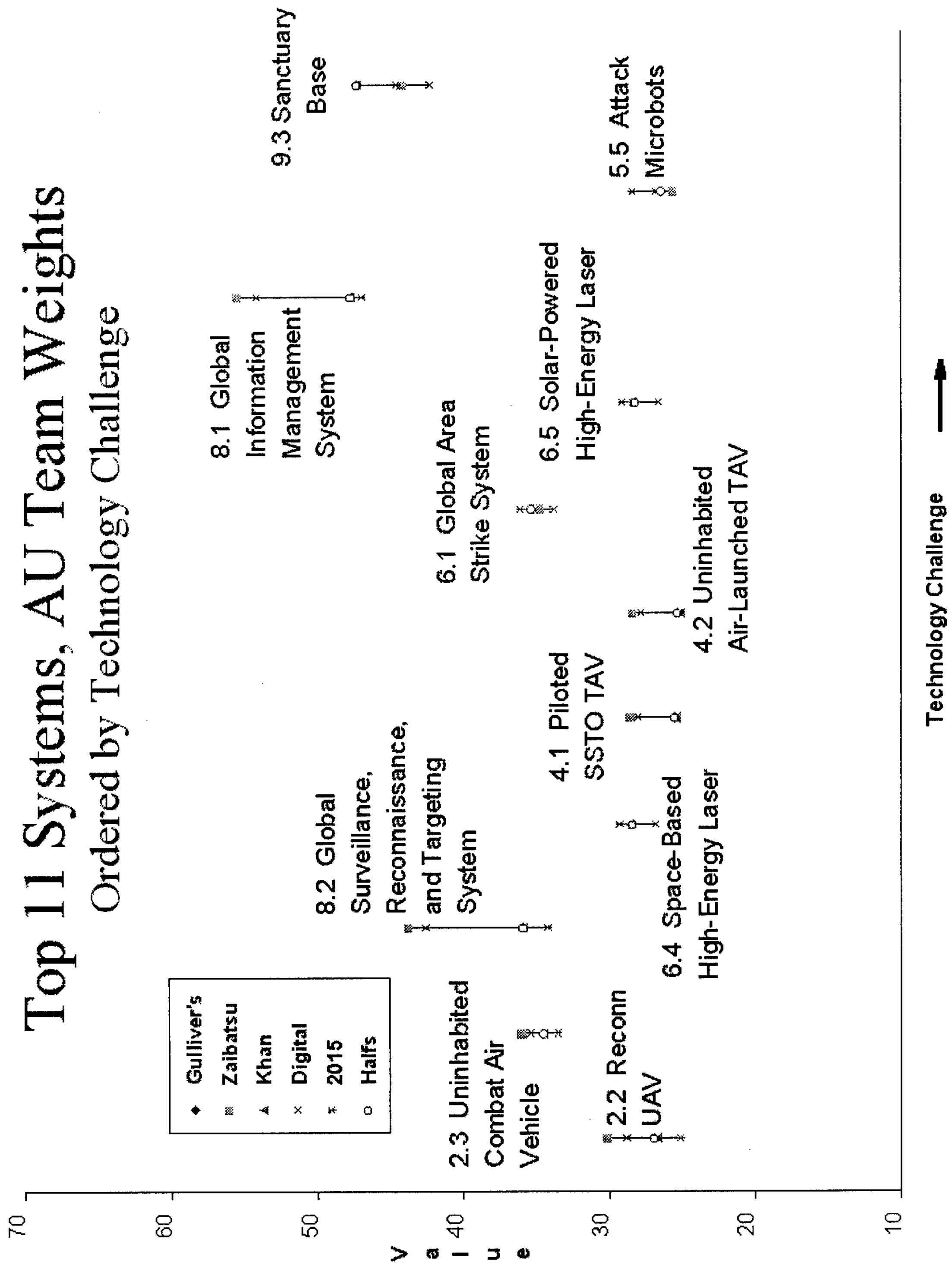


Figure 3-4. Top 11 Systems—AU Team Weights

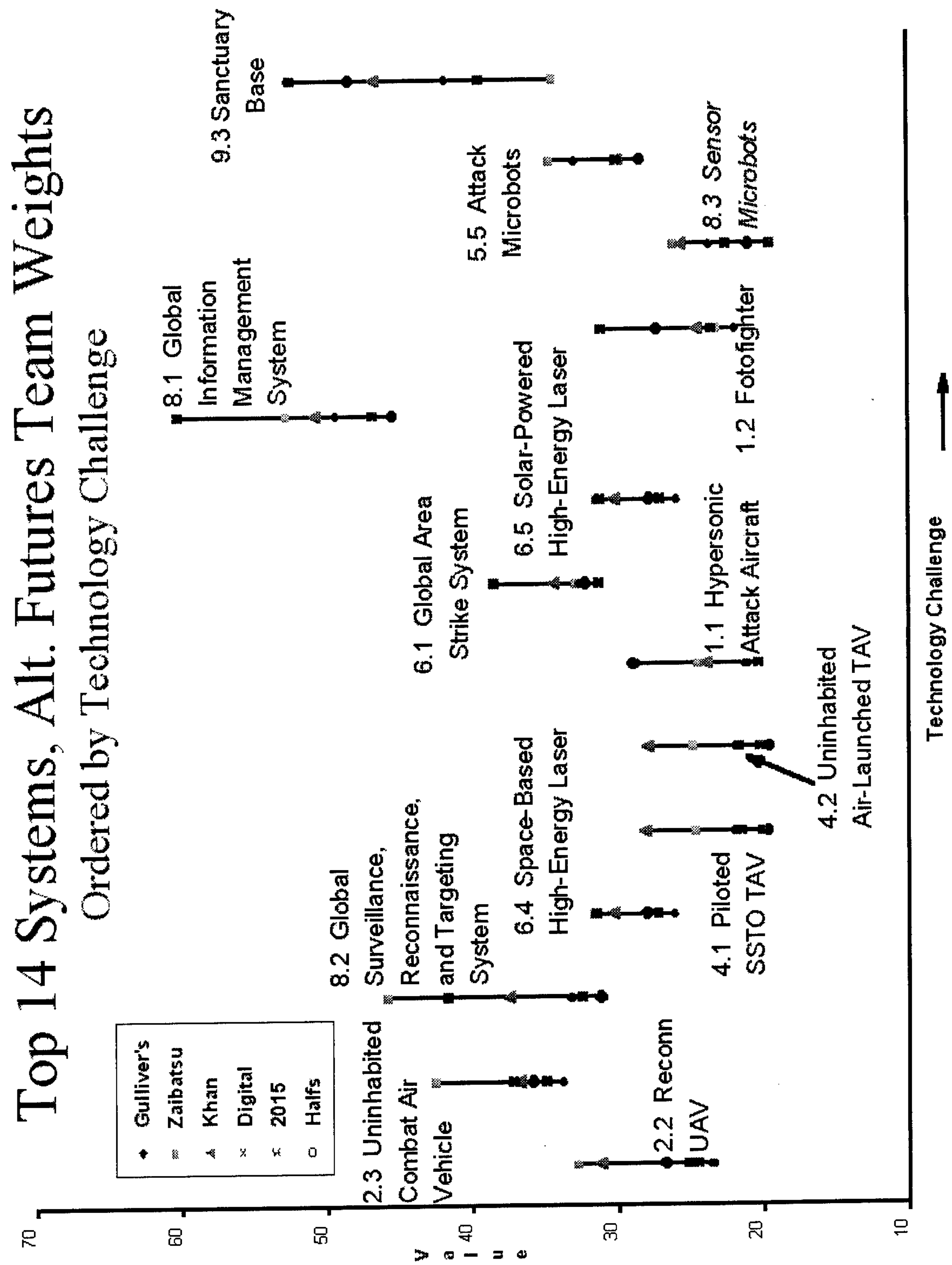


Figure 3-5. Top 14 Systems—Alternate Futures Weights

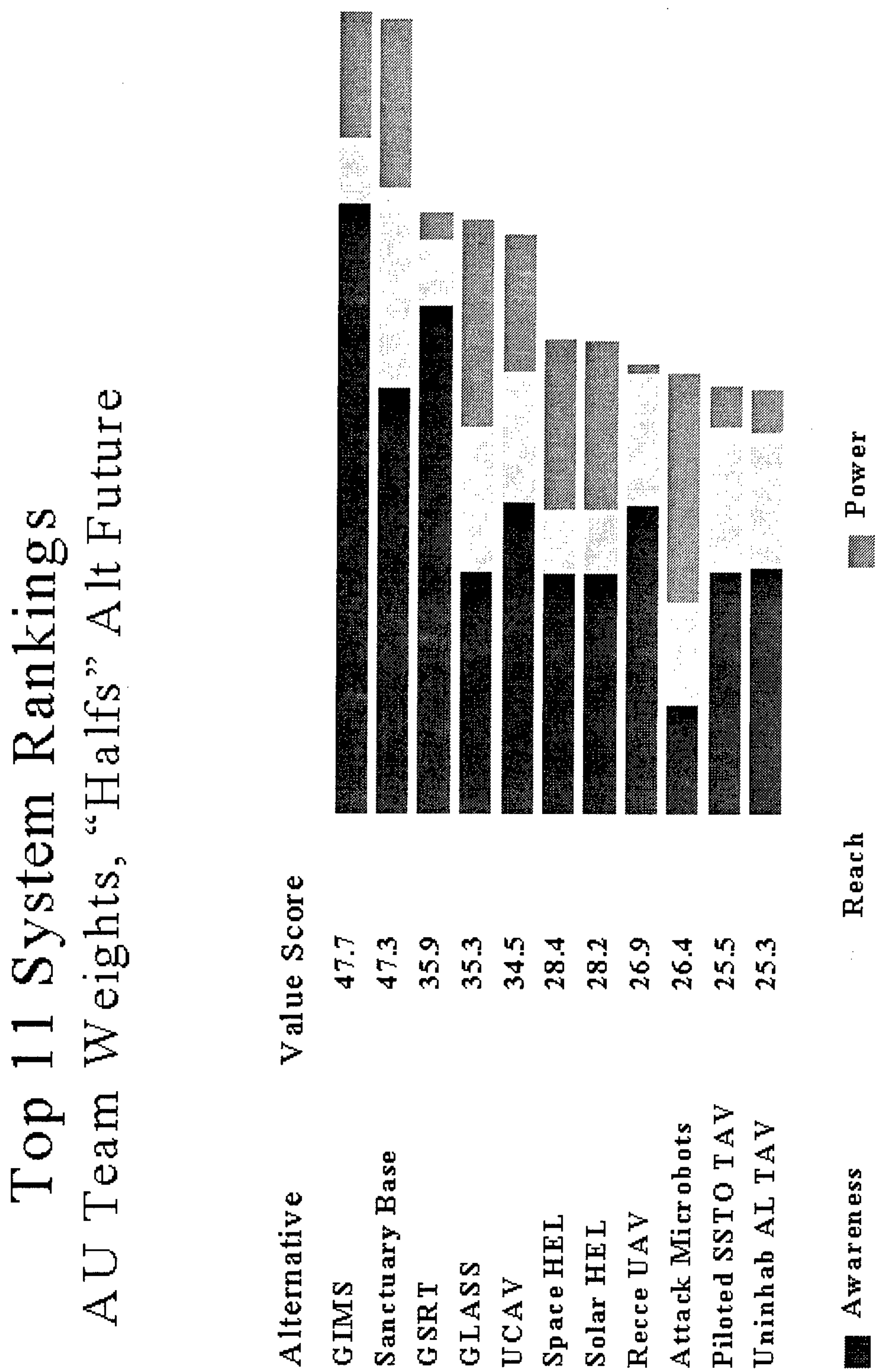


Figure 3-6. Top 11 System Rankings

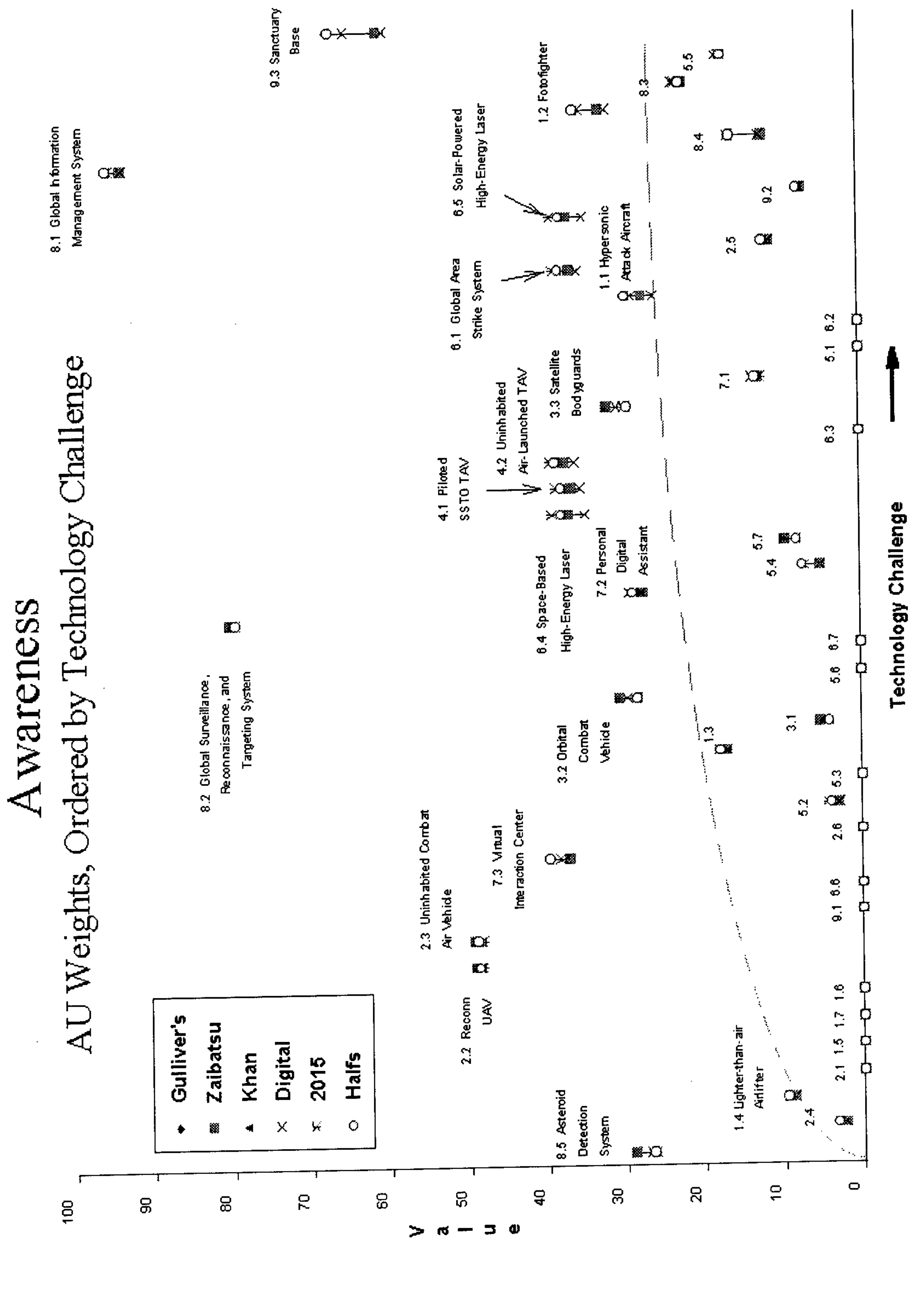


Figure 3-7. *Awareness* Scores—AU Team Weights

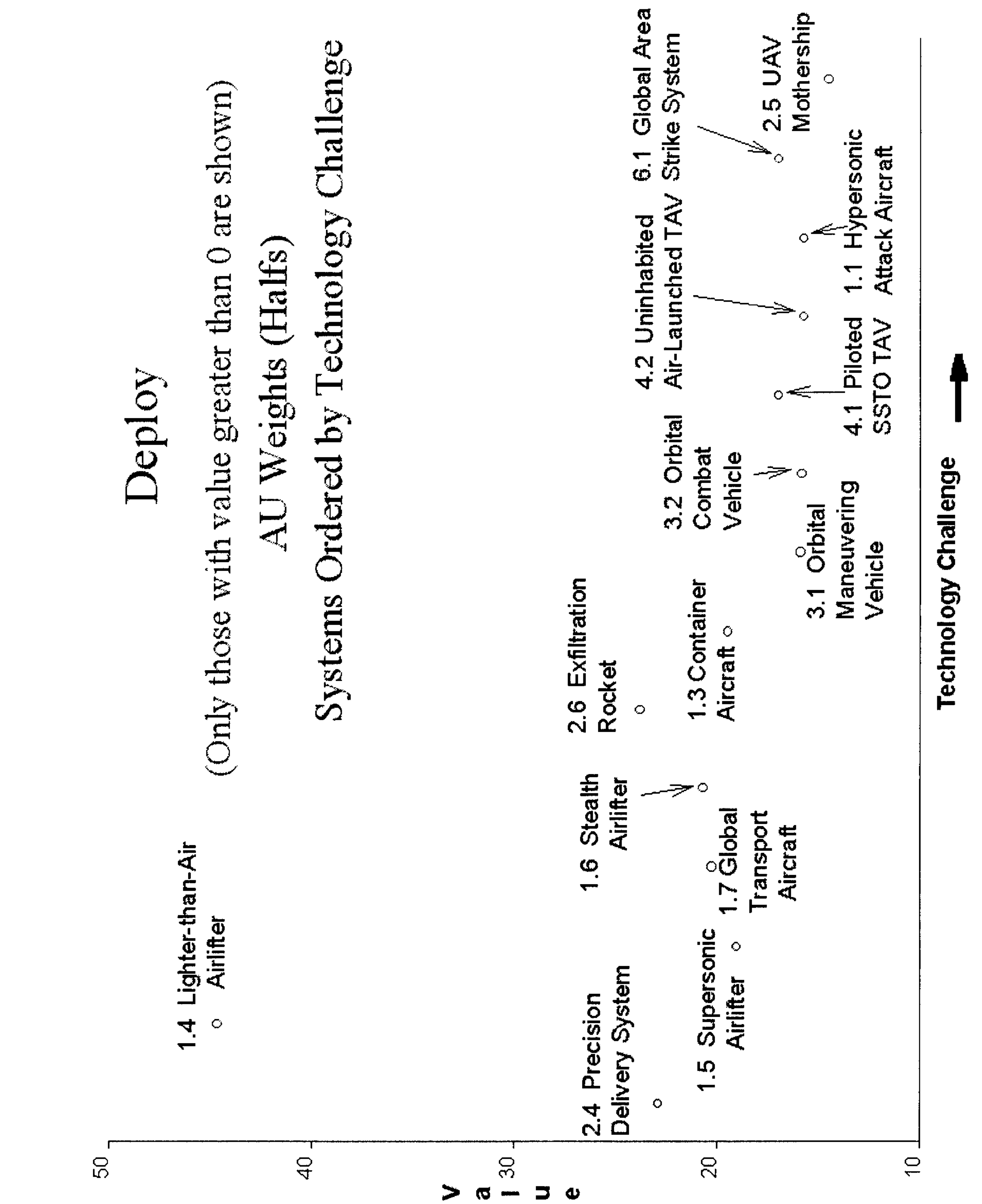


Figure 3-8. ***Deploy*** **Scores—AU Team Weights, Halfs Future**

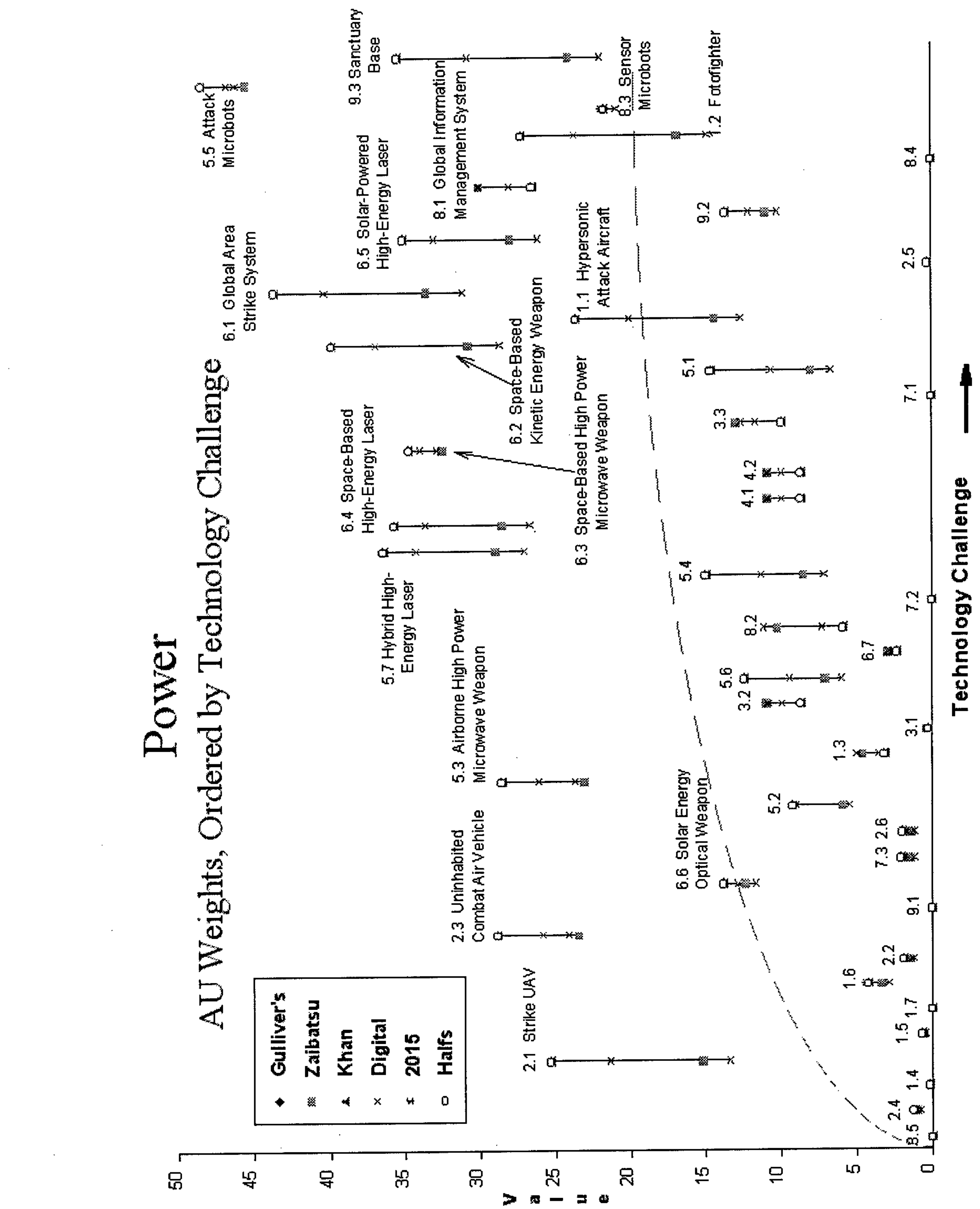


Figure 3-9. *Power* Scores—AU Team Weights

highlights the best systems in terms of the *awareness* function. Such a level of detail may prove useful when conducting mission area analysis to determine required improvements for specific functional areas. In fact, the software used in this analysis can display the system scores at any level of the value model.

Scoring the Technologies

The baseline technology assessment is summarized in figure 3-10 for each of the alternate futures. This assessment considers all 43 systems scored and the Value Model was weighted by all AU white paper writing teams. The score for each technology area was calculated by multiplying the percentage dependence of each of the systems on that development technology by the score that system received in the Value Model. The scores were then summed across the systems with the final result being normalized to a maximum score of 100. These scores are measures of the potential of each enabling technology to improve operational effectiveness in air and space.

Using the "Halfs and Half-Naughts" alternate future, which is placed in the center of the strategic planning space for this study, the technology areas clearly divide themselves into three groupings: the top seven technologies (high leverage), the next five technologies (moderate leverage), and the bottom 31 technologies (lesser leverage). Figure 3-11 shows an expanded view of the top two technology groupings for each alternate future.

As a verification of these results, the Analysis team decided to examine the analysis of the technologies by considering their interaction with only the 11 top-scoring systems. These results are shown in figure 3-12 and figure 3-13. Figure 3-12 shows that the three technology groups generally remained, although the top two groupings contain six technology areas each rather than seven and five, respectively, as in the previous case. The six high-leverage technologies all appeared in the previous high-leverage grouping. Further, 11 of the top 12 technologies remained the same. Lastly, seven of the total 43 technology areas were not applicable when the systems considered were narrowed to the 11 top-scoring ones.

Within technology groupings, the rank changed when going from considering all 43 systems to only considering the 11 top-scoring systems. However, with only three exceptions, technology areas did not change their respective groupings. These exceptions were Aerospace Structures (9.5.4) and Vehicle Flight Control (7.3), which both dropped to a lower technology grouping, from high and moderate leverage to moderate and less leverage, and Communications (5.1), which jumped to a higher technology grouping from lesser leverage to moderate leverage. The results of these two assessments are summarized in table 2 for the high and moderate leverage technologies. The numbers in parentheses indicate the appropriate MCTL category which further defines the technology area.

A sensitivity study also was performed using the Value Model as weighted by the alternate futures team only. As noted in the previous chapter, these weights had a larger variance than the weights from all AU student teams. The results when all 43 systems were considered are given in figure 3-14 and figure 3-15; figure 3-16 and figure 3-17 show the results when the systems considered were narrowed to the 11 top-scoring ones. Although the variance bars increased in length, the basic conclusions did not change with this new set of weights. Appendix F lists numerical data for both the raw and weighted scores for each technology area.

A common trend among the higher leverage technologies was that they had wide applicability over the systems considered. When all 43 systems were considered, the high leverage technologies scored in at least 13 different systems; the maximum number of systems where any technology area scored was 27. Moderate

TABLE 2

TECHNOLOGY ASSESSMENT

	ALL 43 SYSTEMS	TOP 11 SYSTEMS
HIGH LEVERAGE TECHNOLOGIES	Power Systems (10.3) Advanced Materials (1.0) Aerospace Structures (9.5.4) High Performance Computing (4.1.1) Micromechanical Devices (2.6) High-Energy Propellants (12.7) Data-Fusion (4.2.5)	Date Fusion (4.2.5) Power Systems (10.3) Micromechanical Devices (2.6) Advanced Materials (1.0) High-Energy Propellants (12.7) High-Performance Computing (4.1.1)
MODERATE LEVERAGE TECHNOLOGIES	Artificial Intelligence (4.2.9) High-Energy Laser Systems (11.1) Vehicle Flight Control (7.3) Image Processing (4.1.4) Optics (10.2)	High-Energy Laser Systems (11.1) Artificial Intelligence (4.2.9) Optics (10.2) Image Processing (4.1.4) Aerospace Structures (9.5.4) Communications (5.1)

leverage technologies scored in eight of 12 different systems. When the systems considered were reduced to the 11 top-scoring ones, the high leverage technologies scored in at least five systems; the maximum number of systems where any technology area scored was nine. Moderate leverage technologies scored in either three or four different systems. In both assessments, High-Performance Computing (4.1.1) was the technology area with the broadest coverage over the systems considered.

After each technology area had been scored, AFIT's Graduate School of Engineering assembled a committee from its senior staff to determine the key technology driver, the DOD or the commercial sector, for that particular area. They further ascertained the direction of each developmental effort, whether from the DOD to the commercial sector, from the commercial sector to the DOD, or remaining constant. Table 3 summarizes the key technology development leaders; two technology areas, 6.9 Other Sensor and 9.8 Other Propulsion, were not considered in this assessment because of the extremely broad coverage of their respective areas.

TABLE 3
TECHNOLOGY DEVELOPMENT LEADERS

KEY TECHNOLOGY	DOD LEAD	BOTH DOD & COMM	COMM LEAD
1.0 Materials Technology		X	
2.0 Industrial Production			
2.1 Auto of Ind Process, Sys, and Fact			X→
2.2 Metal Working and Ind Production			
2.2.1 Num Contr Machine Tools			X→
2.2.5 Robots, Contr, & Effectors		X	
2.6 Micromechanical Devices		X→	
4.0 Computer Technology			
4.1 Digital Processing			
4.1.1 High-Performance Computing			X
4.1.2 Dyn Training and Simulation		X	
4.1.3 Signal Processing		X	
4.1.4 Image Processing		X	
4.1.6 Speech Processing		X	
4.2 Software			
4.2.4 Hard Real-Time Systems	X→		
4.2.5 Data Fusion	X→		
4.2.9 Artifical Intelligence			←X
4.3 Hybrid Computing		X	
5.0 Telecommunications Technology			
5.1 Transmission			X
5.3 Comm Net Mgmt & Control			X
5.4 C^3I Systems	←X		
5.5 Information Security		X	
6.0 Sensors and Elect Combat Technology			
6.1 Acoustic Systems	X→		
6.2 Optical Sensors	X→		
6.4 Electronic Combat	←X		
6.6 Magnetometers	X→		
6.7 Gravity Meters	X		
6.8 Radar	X→		
6.9 Other Sensor			
7.0 Nav, Guid, and Vehicle Contr Tech			
7.3 Vehicle and Flight Control		X	
9.0 Propulsion and Vehicular Sys Tech			
9.1 Gas Turbine Propulsion Systems		X	
9.2 RAMjet, SCRAMjet, and CC Engine	←X		
9.4 Rockets	X (no NASA)	X (if NASA)	
9.5 Aerospace Structures and Systems			
9.5.1 Spacecraft Structures		X	
9.5.2 Non-Chem, High-Isp Prop	←X		
9.5.4 Aircraft High-Perf Structures	←X		
9.8 Other Propulsion			
10.0 Laser, Optics and Power Sys Tech			
10.1 Lasers		X	
10.2 Optics			X
10.3 Power Systems	X		
11.0 Directed Energy & Kinetic Energy Sys			
11.1 High-Energy Laser Systems	←X		
11.2 High-Power Radio Freq Sys	←X		
11.4 Kinetic Energy Systems			
11.4.2 Kinetic Energy Projectiles	←X		
11.4.4 KE Platform Management	←X		
12.0 Munitions Dev & Energetic Mat'l Tech			
12.1 Warheads, Ammo, & Payloads	←X		
12.7 Mil Explosives (Energetic Mat'l)	X		
13.0 Chemical & Biological Systems Tech			
13.3 CBW Defensive Systems	X		

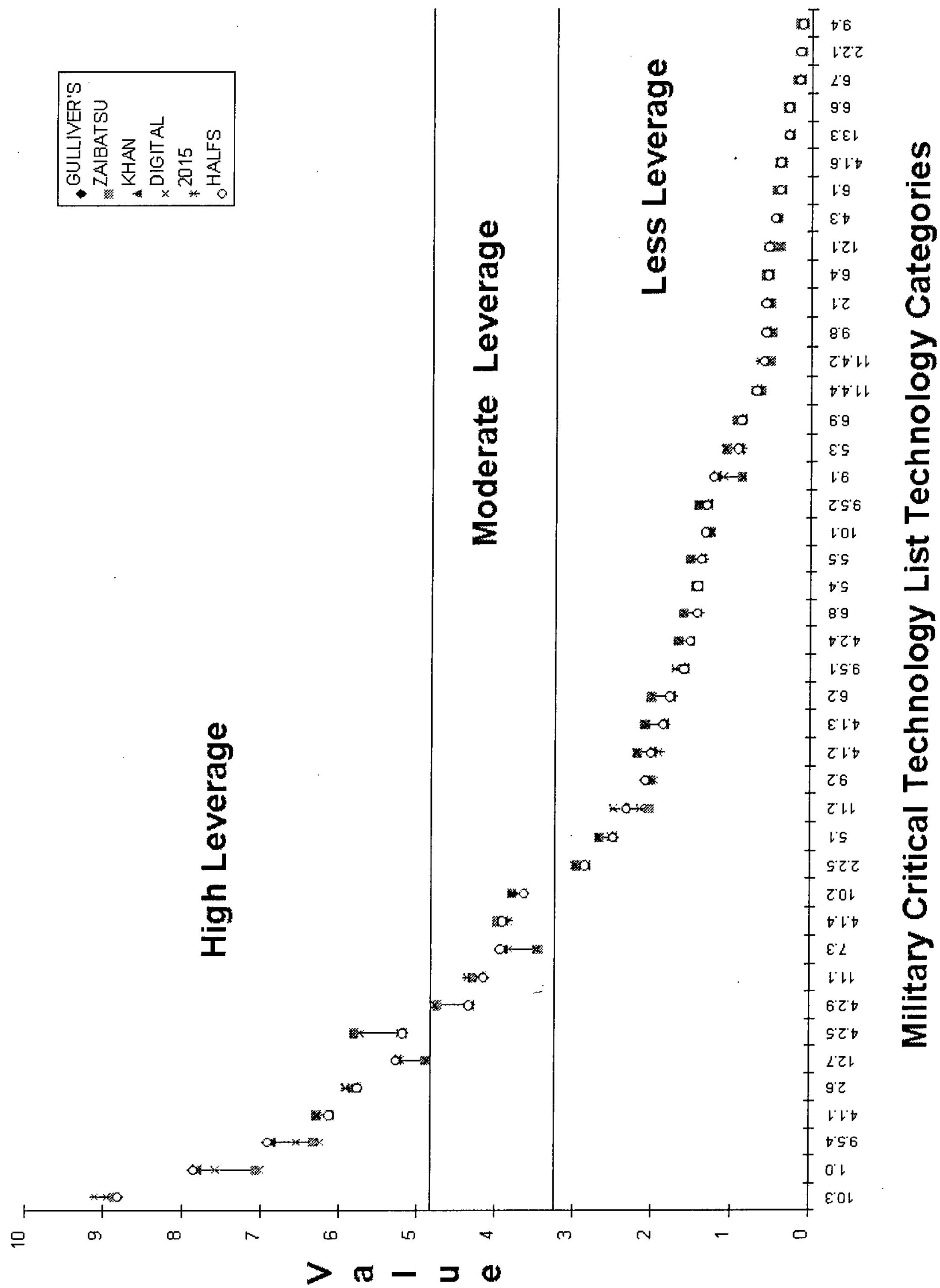


Figure 3-10. Technology Rankings (All 43 Systems, AU Students Weights)

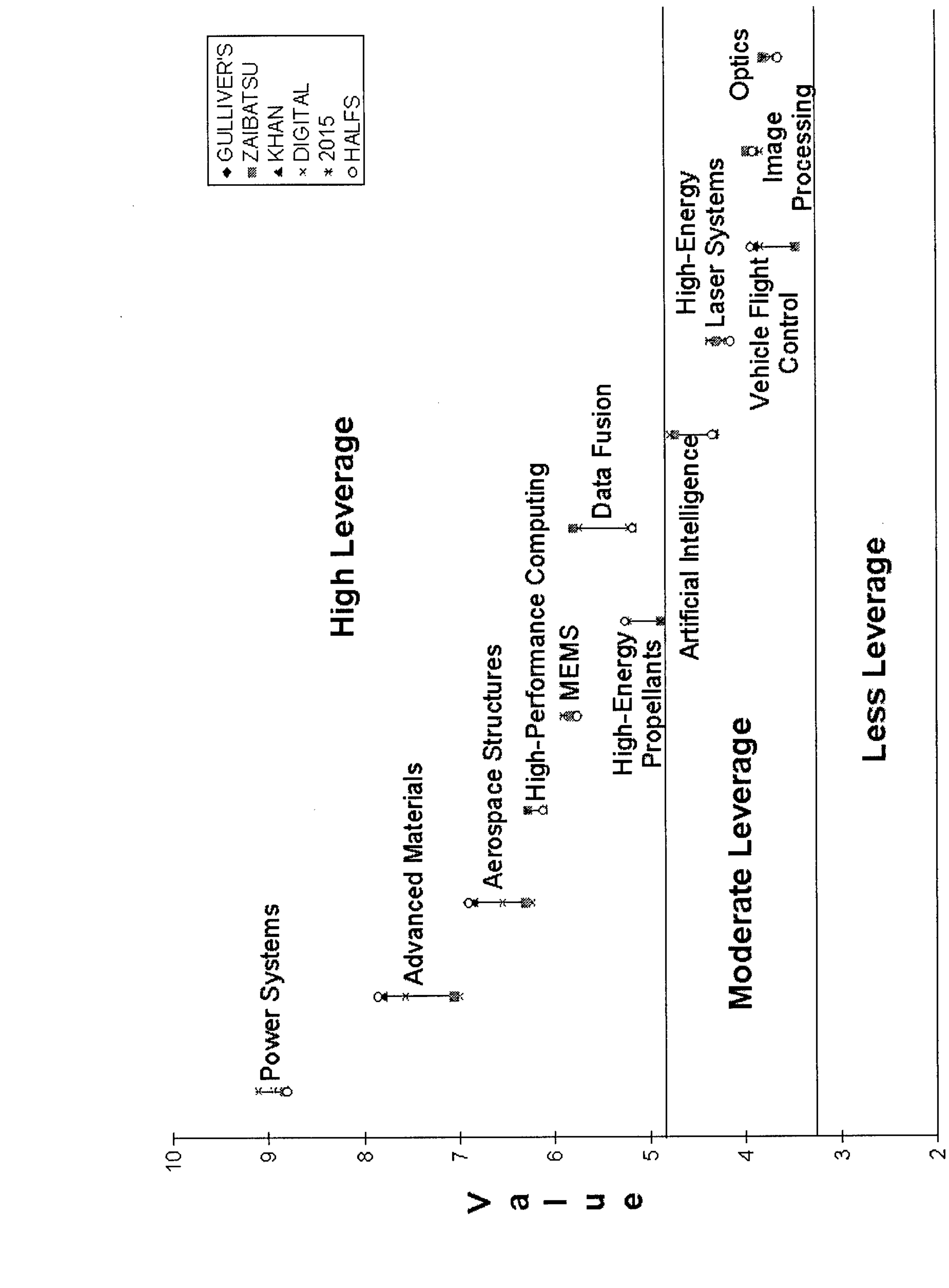


Figure 3-11. Top 12 Technology Rankings (All 43 Systems, AU Students Weights)

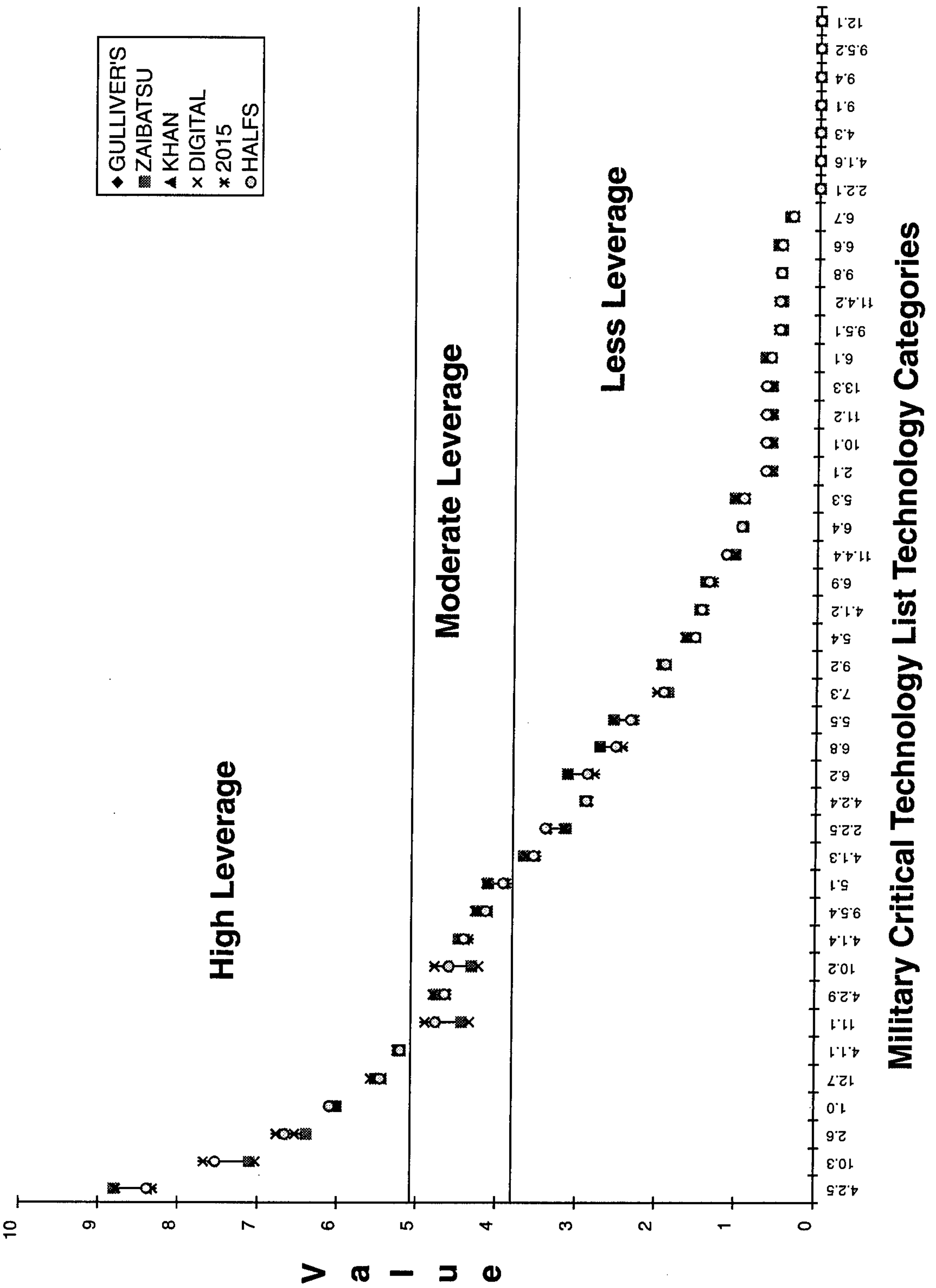


Figure 3-12. Technology Rankings (Top 11 Systems, AU Students Weights)

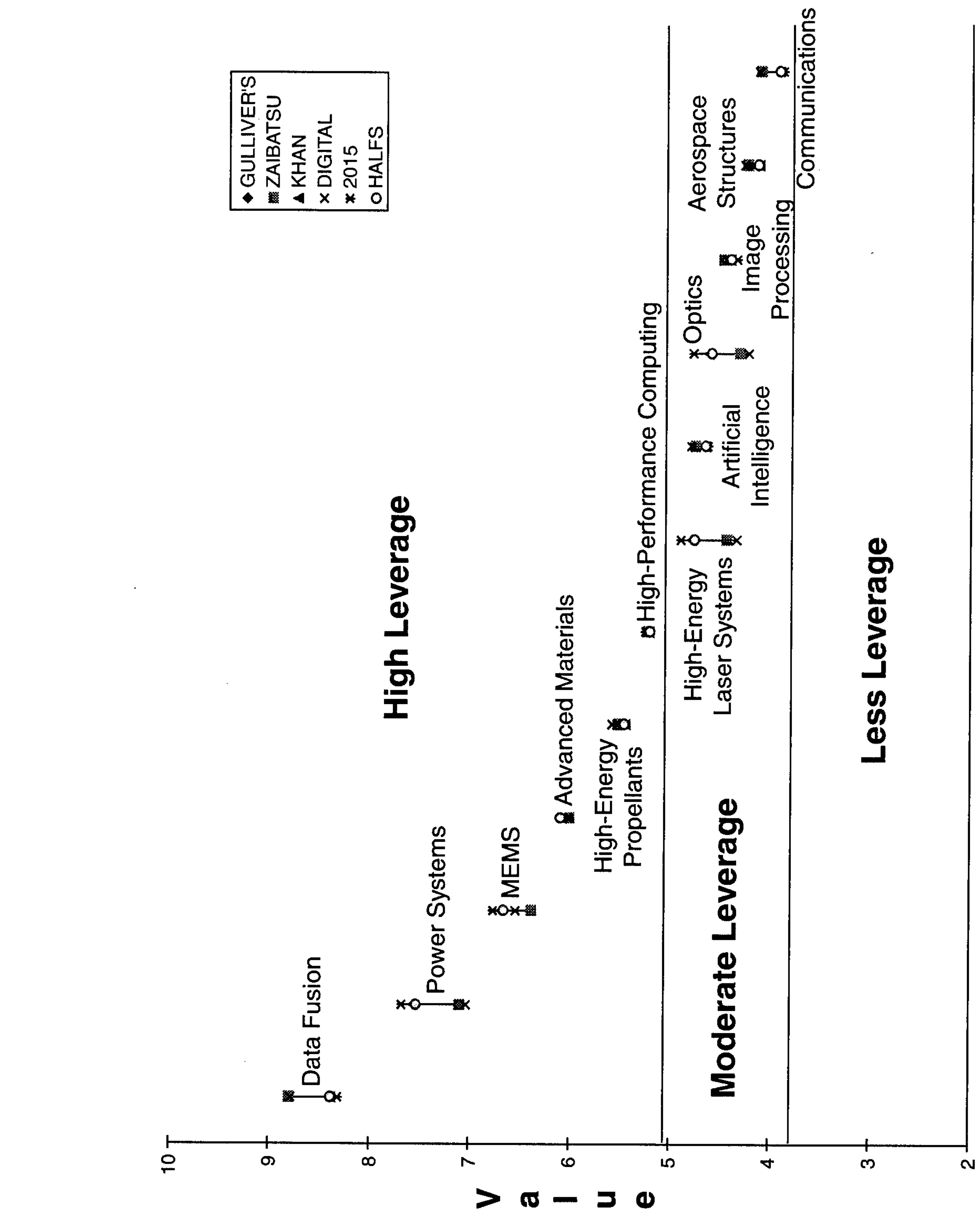


Figure 3-13. Top 12 Technology Rankings (Top 11 Systems, AU Students Weights)

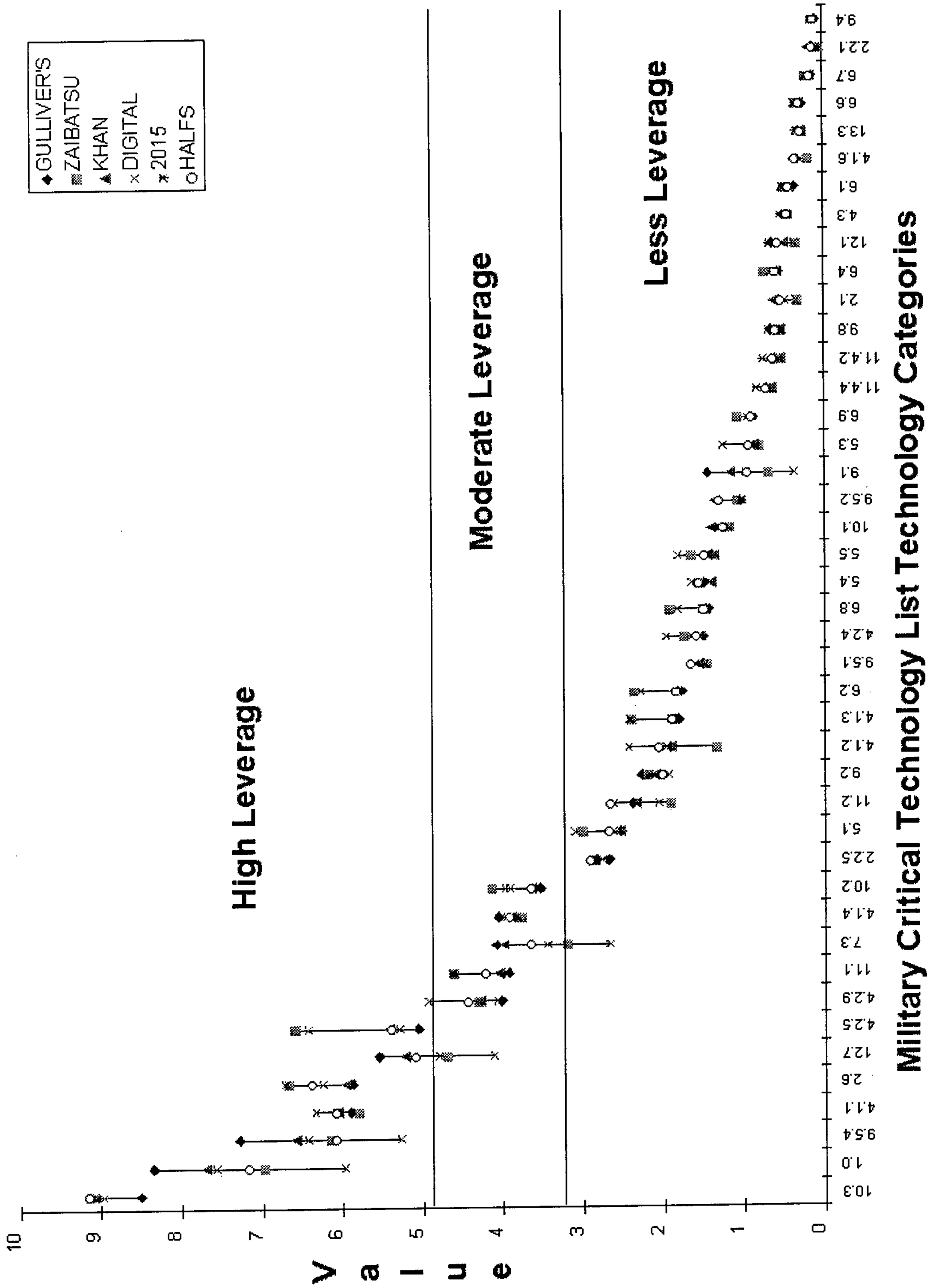


Figure 3-14. Technology Rankings (All 43 Systems, Alternate Futures Team Weights)

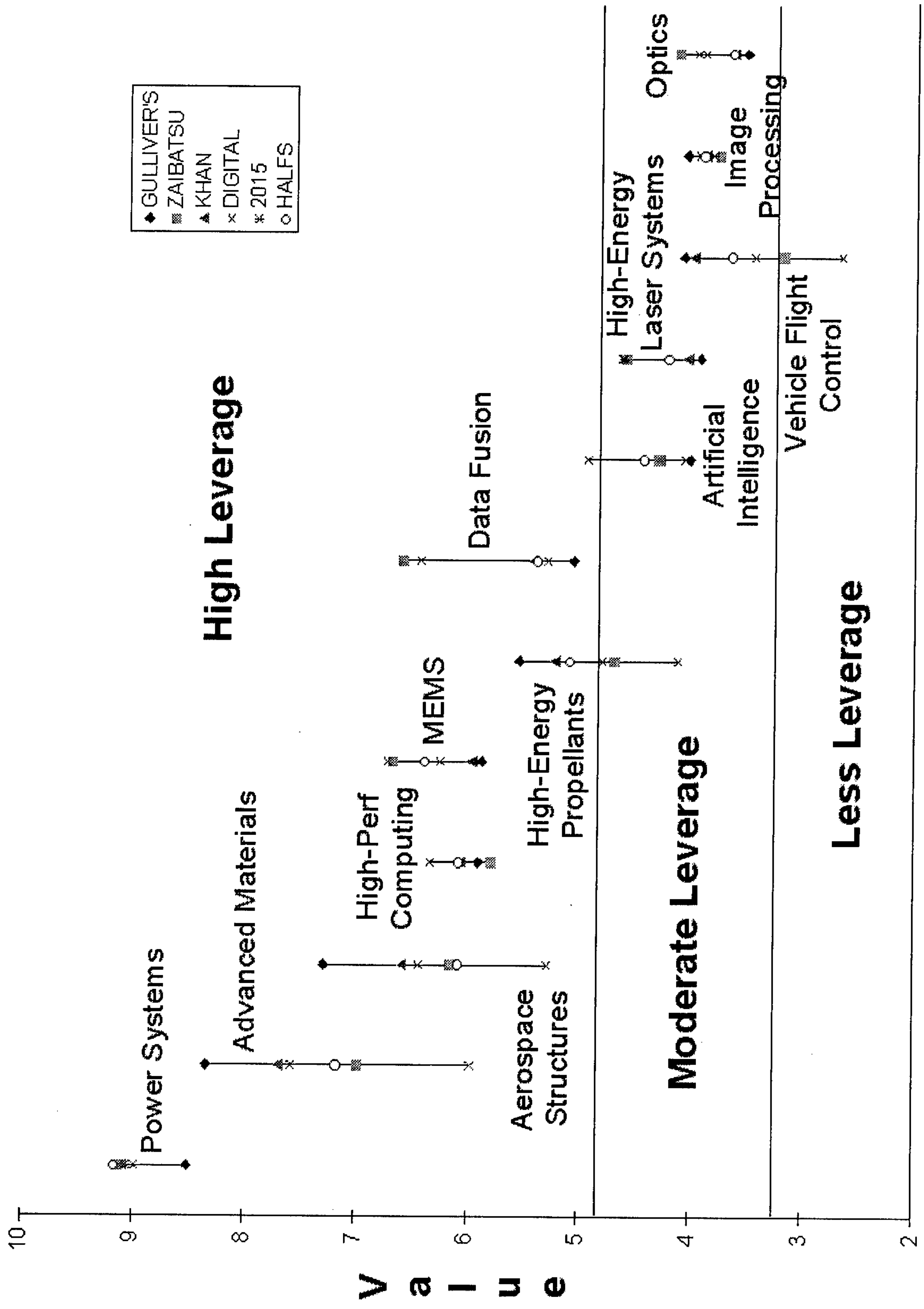


Figure 3-15. Top 12 Technology Rankings (All 43 Systems, Alternate Futures Team Weights)

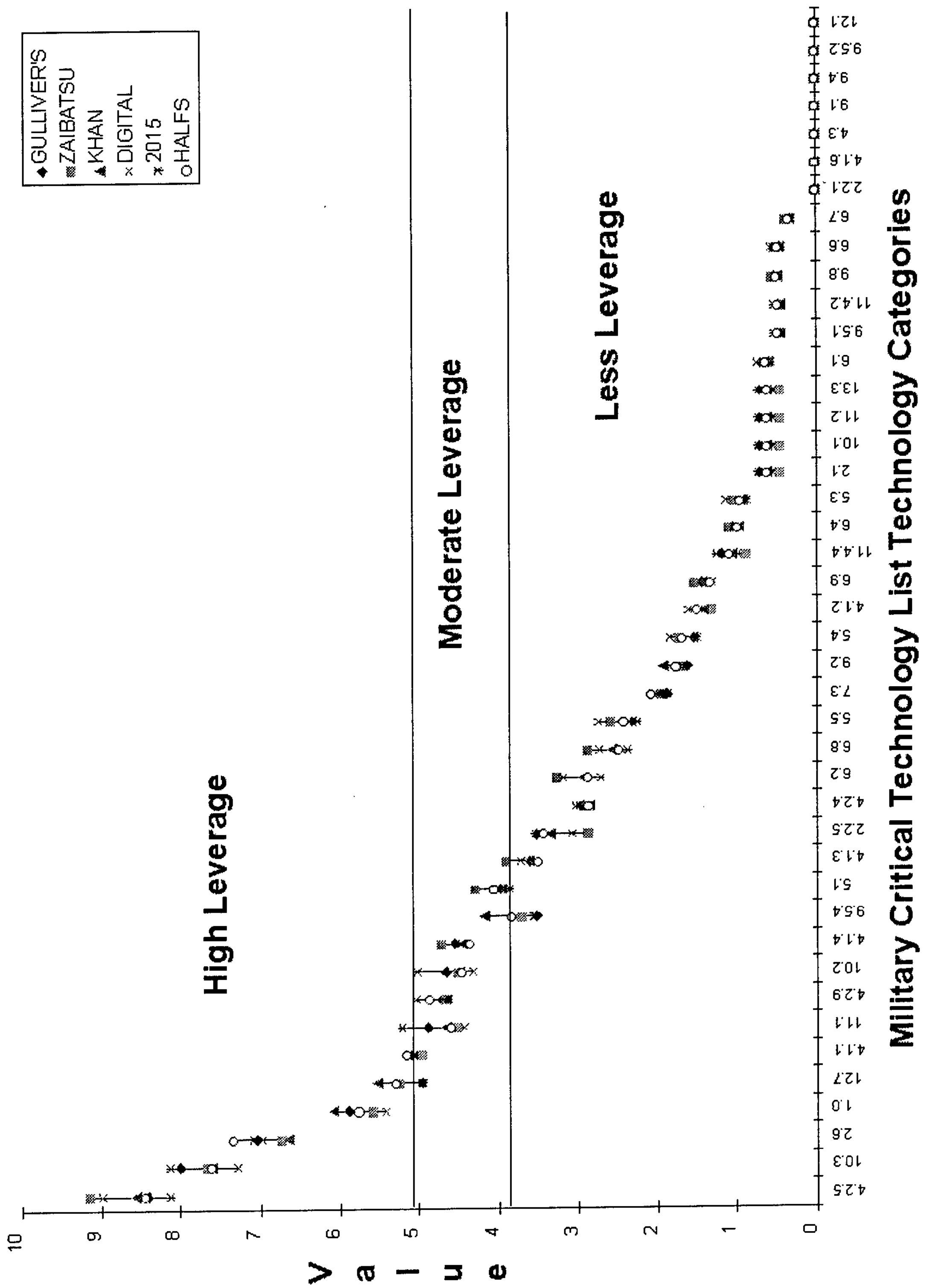


Figure 3-16. Technology Rankings (Top 11 Systems, Alternate Futures Team Weights)

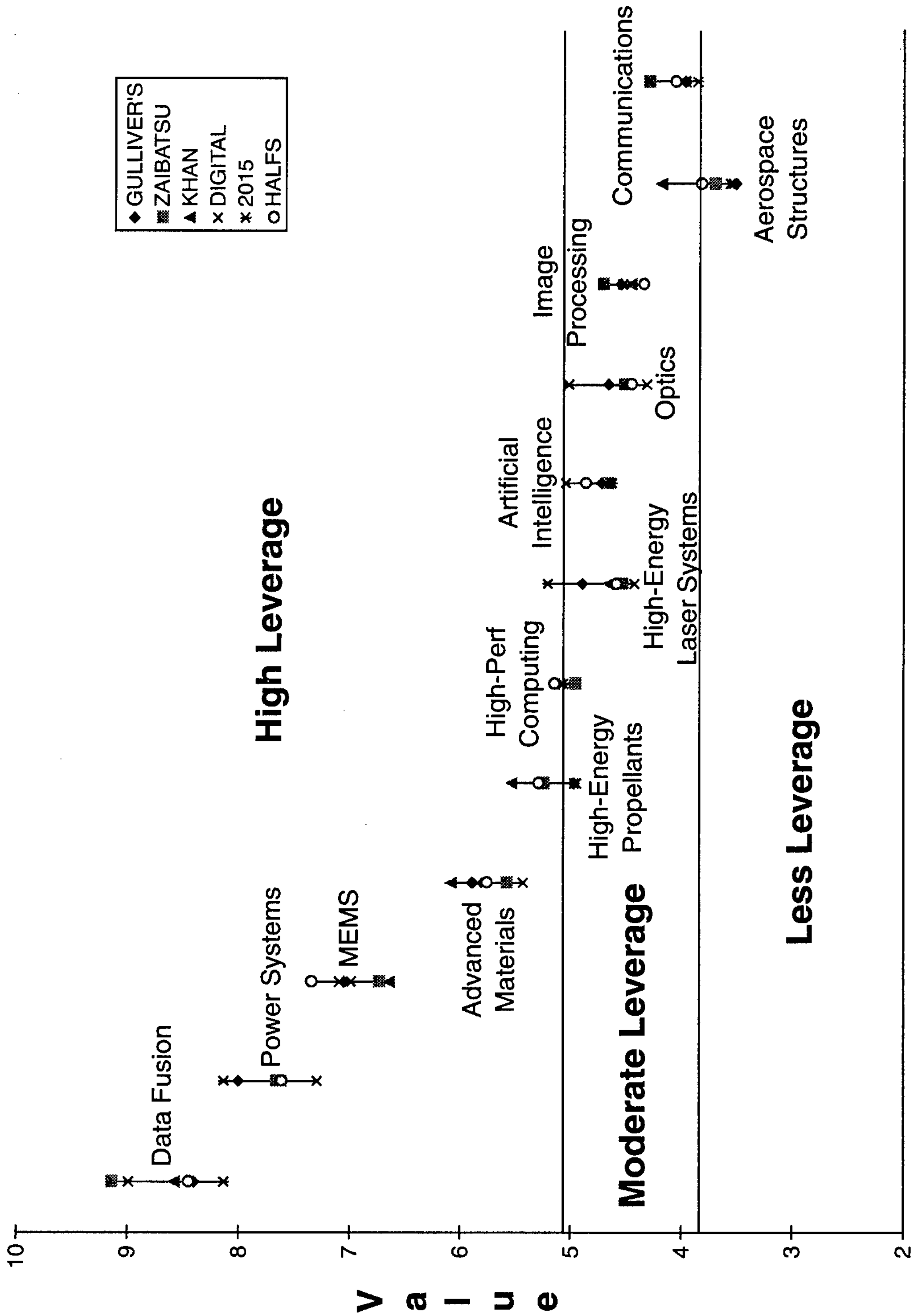


Figure 3-17. Top 12 Technology Rankings (Top 11 Systems, Alternate Futures Team Weights)

Chapter 4

Conclusions

The ***2025*** Operational Analysis was a milestone in the ***2025*** process and provided a number of unique contributions. Most importantly, it met its fundamental purpose—the OA identified future air and space systems required to dominate combat and the key technologies that will make those systems possible. Further contributions will be covered in the following order:

- the major implications of the study results,
- the lessons learned during the ***2025*** OA process,
- the limitations of the study,
- and the major implications of the ***2025*** OA for the future.

Major Implications of the *2025* OA

This analysis contends that the high ground of improved *awareness* offers significant potential for achieving future air and space dominance. Typically, top-scoring systems possessed higher degrees of *awareness* and/or were predominantly space systems:

- Global Information Management System (GIMS)
- Sanctuary Base (SB)
- Global Surveillance, Reconnaissance, and Targeting System (GSRT)
- Global Area Strike System (GLASS)
- Uninhabited Combat Air Vehicle (UCAV)
- Space-Based High-Energy Laser (Space HEL)
- Solar High-Energy Laser (Solar HEL)
- Reconnaissance Unmanned Air Vehicle (Recon UAV)
- Attack Microbots
- Piloted Single Stage Transatmospheric Vehicle (TAV)
- Uninhabited Air-Launched TAV

Seven of the top eight systems emphasized the *awareness* function. *GSRT* can be thought of as a first generation *GIMS*; it obtains most of the value of *GIMS* with much less technological challenge. Both systems scored high because the management of information tasks were assigned high weights by the ***2025*** white paper writing teams. Such systems go beyond data fusion to knowledge fusion; they provide a global view that could revolutionize military operations. Improved awareness is critically important because it enables virtually all other air and space force capabilities.

This analysis also suggests that control of the high ground of space will be important. Of the top 11 systems, only three do not operate in space or use major space-based components. Space-based weapons are significant contributors to the operational effectiveness of future air and space operations. They provide key capabilities in space defense, ballistic missile defense, defense of terrestrial forces, and terrestrial power projection. Of the weapon systems evaluated, the Space-Based High-Energy Laser seems to hold the most promise, largely because its optical system could also be used for surveillance and imaging missions (an awareness function). Other systems that scored well were the Solar High-Energy Laser, the Space-Based Kinetic Energy Weapon, and the Space-Based High-Powered Microwave. Spacelift is another essential contributor to future space operations (i.e., reusable transatmospheric vehicles provide critical lift capability to improve virtually all space force capabilities).

This analysis also suggests that *improved power* will be best accomplished through improved speed, precision, and on-station time. The ***2025*** white paper writing teams

viewed the reduction of the observe, orient, decide, act (OODA) loop to a OODA "point" as critical to future operations. All of the "shooter" systems that emphasized *awareness* scored high by reducing the time to identify, target, and kill threats. Among these systems are the GLASS, the Space-Based HEL, and the Solar HEL. The envisioned systems emphasized the increased need for precision over mass, especially with respect to avoiding excess collateral damage. For example, the only system with a weapon of mass destruction was the Asteroid Mitigation System, which incorporated a nuclear device.

The constant quick response requirement of future combat meant many of the systems either were *global* or used uninhabited air vehicles (UAV). It is important to note that while the UAV are uninhabited, none are envisioned as operating autonomously without a human in the loop. Such an improved on-station *power* capability is important because it provides a constant deterrent to enemy forces.

Key to this analysis was the use of several possible alternate futures as the basis for the sensitivity analysis. Because the analysis was conducted across a number of alternate futures and the resulting conclusions remain basically the same across those futures for any reasonable set of weights a future decision maker might apply, these systems are an excellent initial set of systems to consider for future employment of air and space power.

The technology assessment portion of the study identified six high leverage technologies that were important to a large number of high-scoring systems:

- Data Fusion
- Power Systems
- Micromechanical Devices
- Advanced Materials
- High-Energy Propellants
- High-Performance Computing

Advances in these areas show promise to improve substantially a wide range of air and space operations. Among the technologies, the only surprise to the Analysis team was that *Power Systems* scored so highly. Other technologies were important also, but contributed to only three or four of the high-value systems. Among the top-scoring medium leverage technologies were

- High-Energy Laser Systems
- Artificial Intelligence
- Optics
- Aerospace Structures
- Image Processing
- Communications

Some of the high leverage technologies enabling ***2025*** systems, including high-performance computing, are being pursued aggressively in the commercial sector. Others, such as data fusion and power systems, have lower commercial value. An expanded analysis of the ***2025*** systems and their embedded technologies can help develop the most effective DOD investment strategy.

OA Process Lessons Learned

Foremost among the ***2025*** OA lessons learned was that the VFT approach worked well. The ***Foundations 2025*** value model has been used to evaluate systems that span the full range of future air and space combat operations. These systems are conceptual system ideas that will require significant R&D to design and evaluate. The OA provided a structure to incorporate the subjective judgments of operational and technical experts to produce objective, traceable, and robust results.

The focus of the Value Model, ***Foundations 2025***, was on the employment of air and space forces. This model does not consider the USAF functional areas required to organize, train, and equip. As it became apparent that none of the current doctrinal frameworks were free of these functional views, the Value Model was developed from the bottom-up. In taking this approach, the Analysis team reduced the institutional biases associated with the numerous

stovepipes in the current USAF organizational structure.

Study Limitations

Remember that the analysis did not take into account the cost or risk of developing any of the system concepts. It looked only briefly at the technological challenge of each system concept. While this study indicates some systems and technologies that show promise for dramatically improving the effectiveness of air and space operations, other important factors need to be considered before making an investment decision.

A consequence of most value models is that a complex system (or system of systems) that performs many tasks generally outscores a similar system that performs only a few of the tasks. Also, for ***Foundations 2025***, a system's sphere of influence is primarily measured by its range which is only one force quality. For example, the Sanctuary Base scores high because it has awareness, reach, and power capabilities. Yet, it has a 500-mile range limitation on most of those capabilities. ***Foundations 2025*** would only show a small difference between the Sanctuary Base and a similar system with global range.

Major Implications for the Future

A number of senior decision makers have viewed the model and commented that the best use of ***Foundations 2025*** may be an analysis of systems within the distinct spheres of *awareness, reach, and power*. They envision separating and developing each function of the model further (refining the tasks, subtasks, force qualities, measures of merit, and scoring functions) and studying which *awareness* (or *reach* or *power*) systems are most promising. These three separate models could be effective mission area analysis tools for the major commands.

The completed ***Foundations 2025*** value model is the starting point for real value-focused thinking. For any function, task, or subtask, the model can be used to evaluate current and projected systems. Next, the acquisition community can focus on how new concepts can be developed to significantly increase value. Many individual and various creativity techniques can be used to develop these new concepts.

Another opportunity to capitalize on the ***Foundations 2025*** model is to use it as a framework for future air and space doctrine. Because it identifies fundamental functions, tasks, and subtasks, it could be the foundation for joint doctrine for future air and space warriors. The ***2025*** analysis techniques could be used to develop an entirely new joint military doctrine free from current institutional bias.

Summary

The ***2025*** operational analysis is an important first step. It is offered as a starting point for further discussion and analysis. The ***2025*** process began with creative thinking. The OA completed the process by identifying the most promising systems and the enabling technologies required to provide dominant air and space power for the United States of America as we enter the twenty-first century.

Appendix A

Foundations 2025 Value Model

This appendix shows the ***Foundations 2025*** Value Model (figure A-1 through figure A-4) and the measures of merit and scoring functions for each of the 134 force qualities (figure A-5 through figure A-32), arranged by subtask. It concludes with a glossary of the terms used in the measures of merit and scoring functions.

Value Model

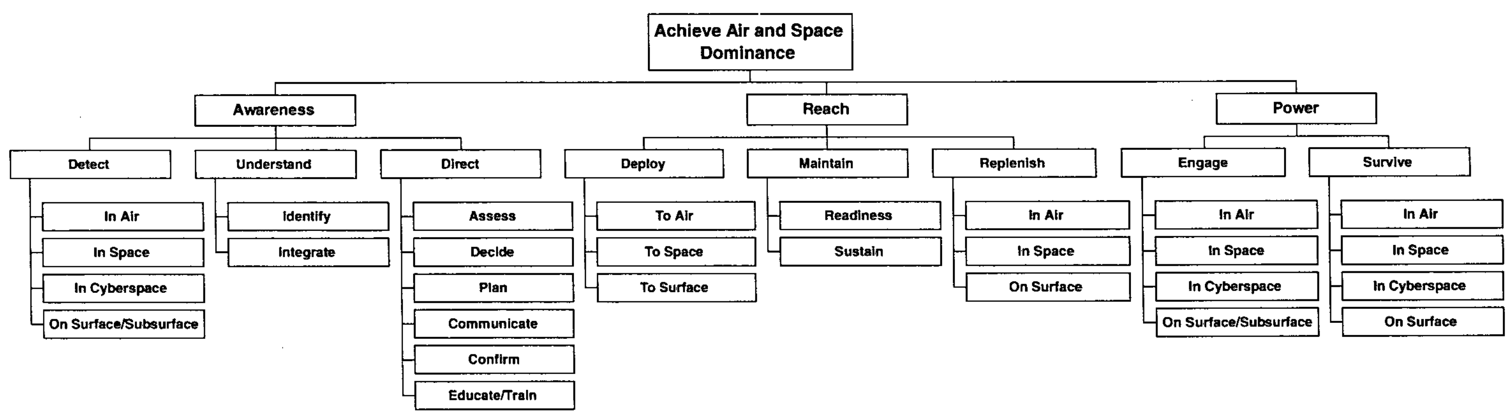


Figure A-1. Value Model—Top Level

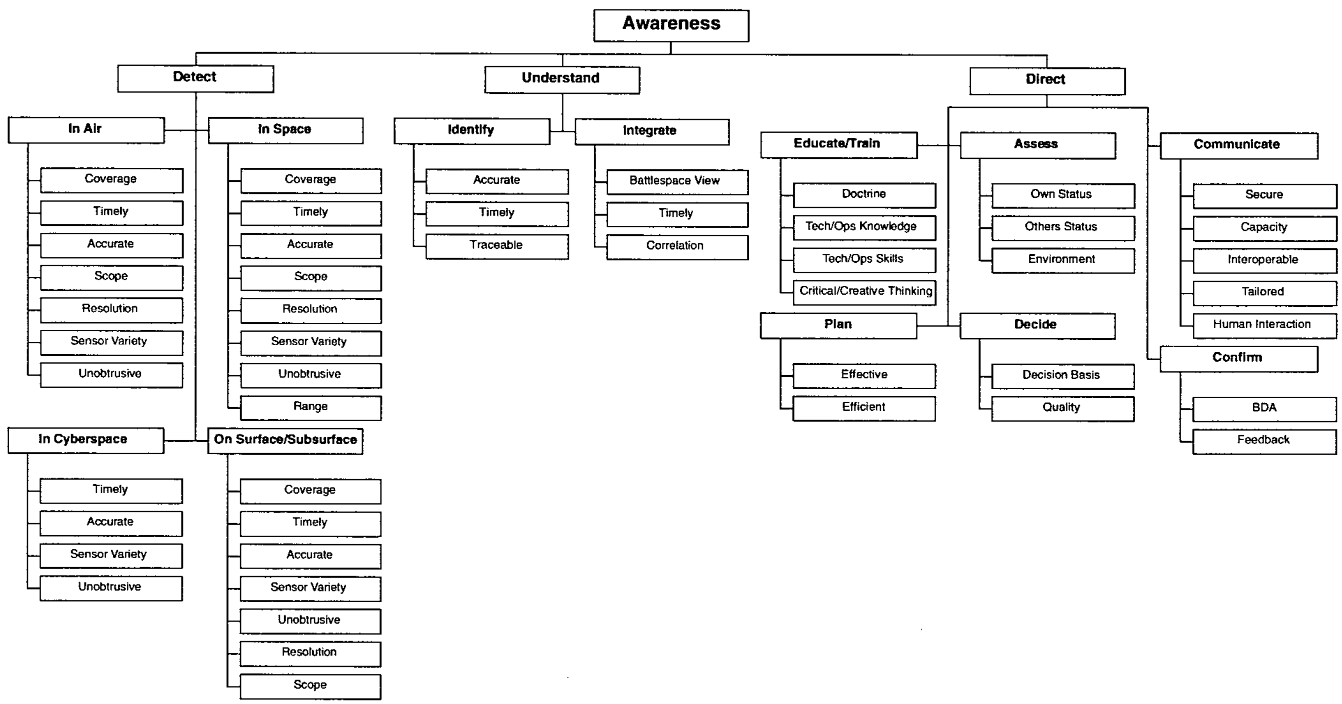


Figure A-2. Value Model—Awareness

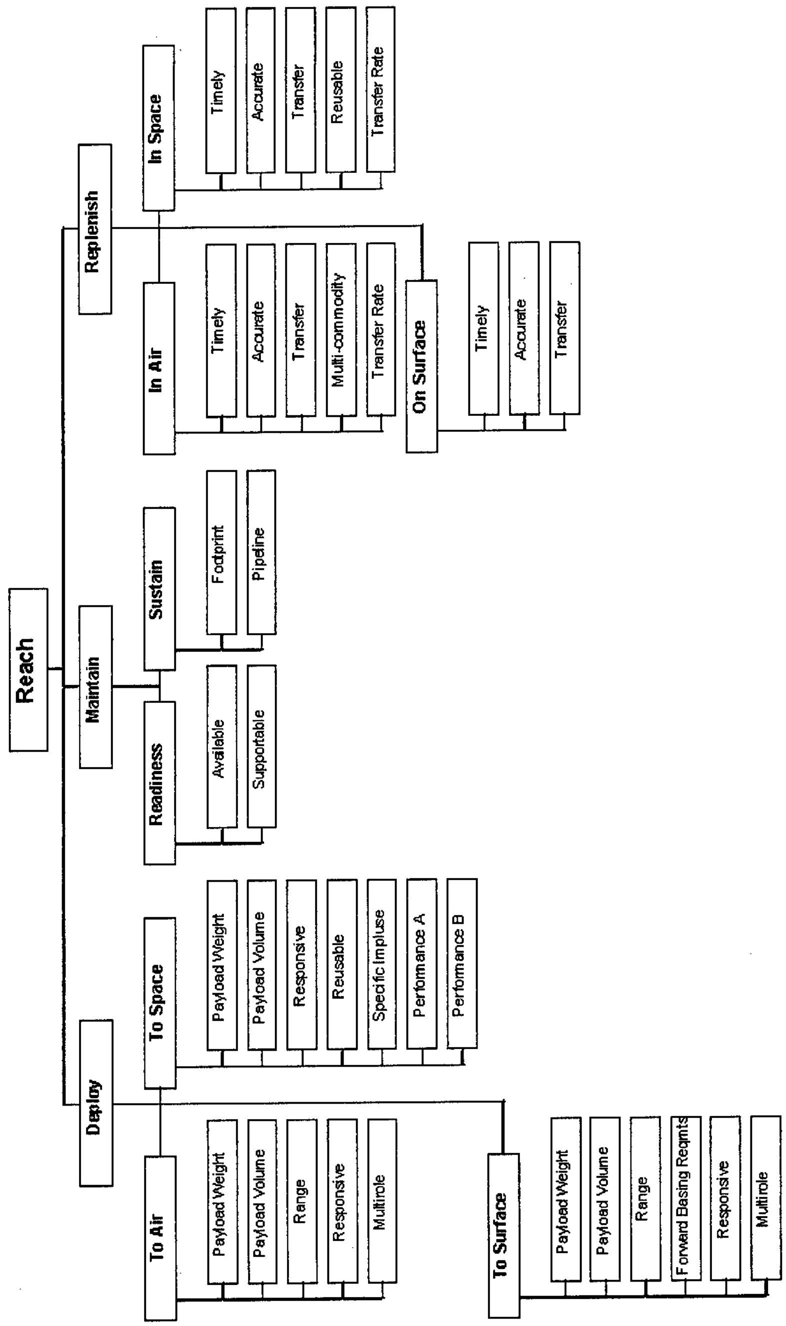


Figure A-3. Value Model—Reach

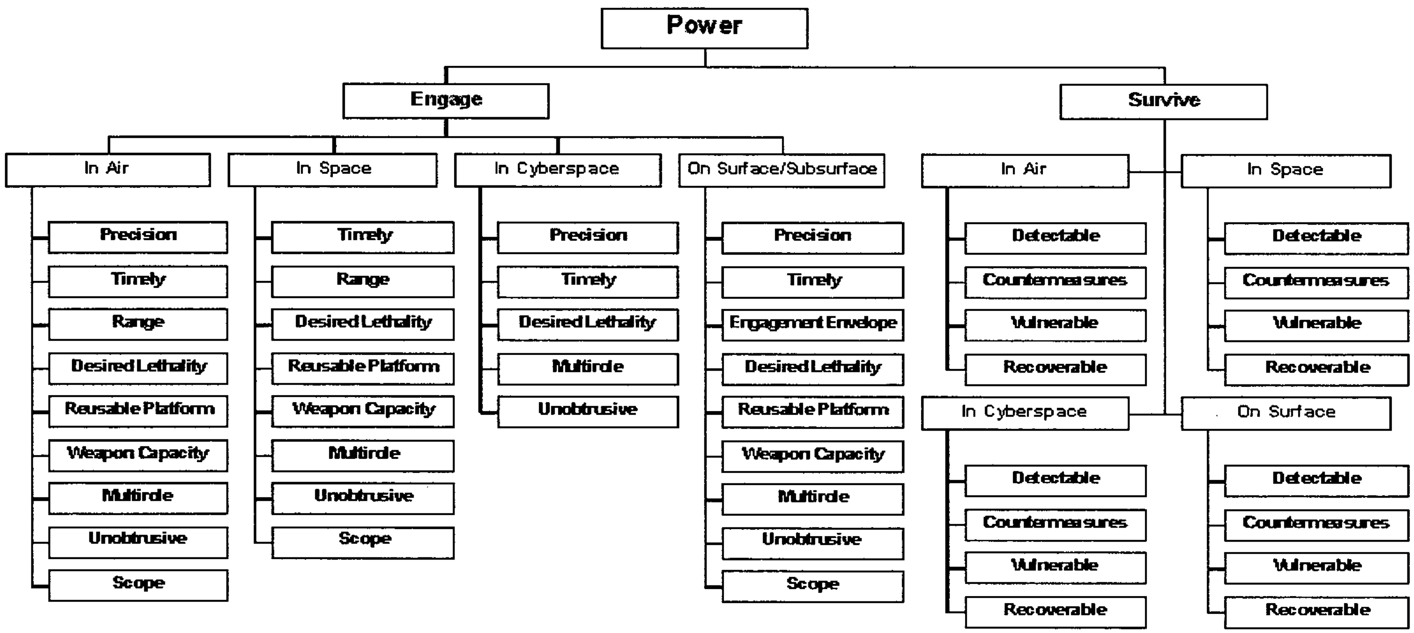


Figure A-4. Value Model—Power

Measures of Merit and Scoring Functions

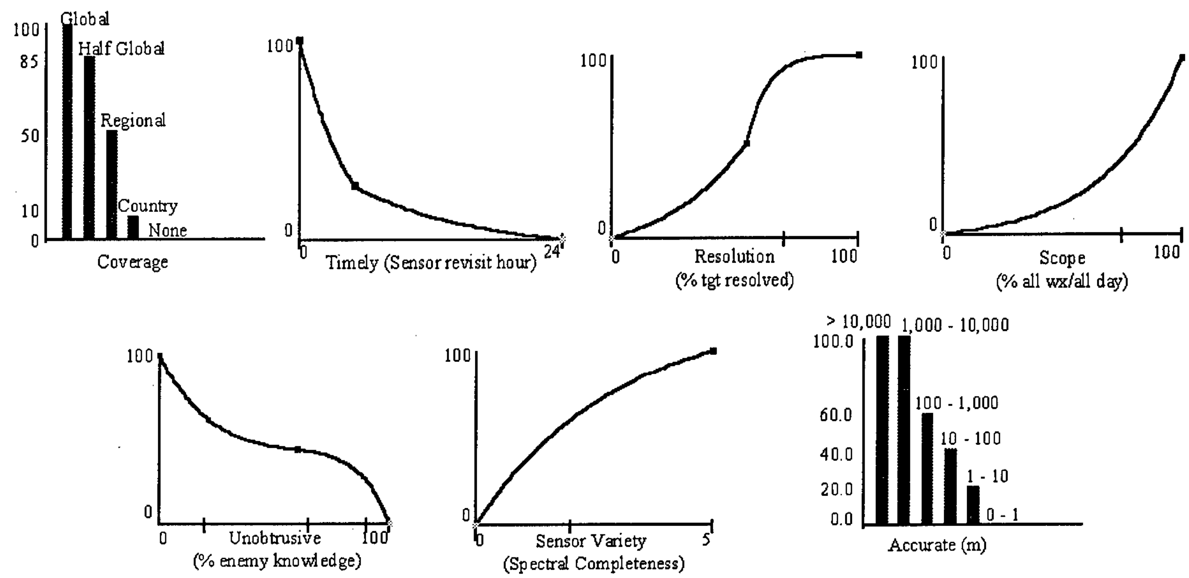


Figure A-5. *Detect in Air* Scoring Functions

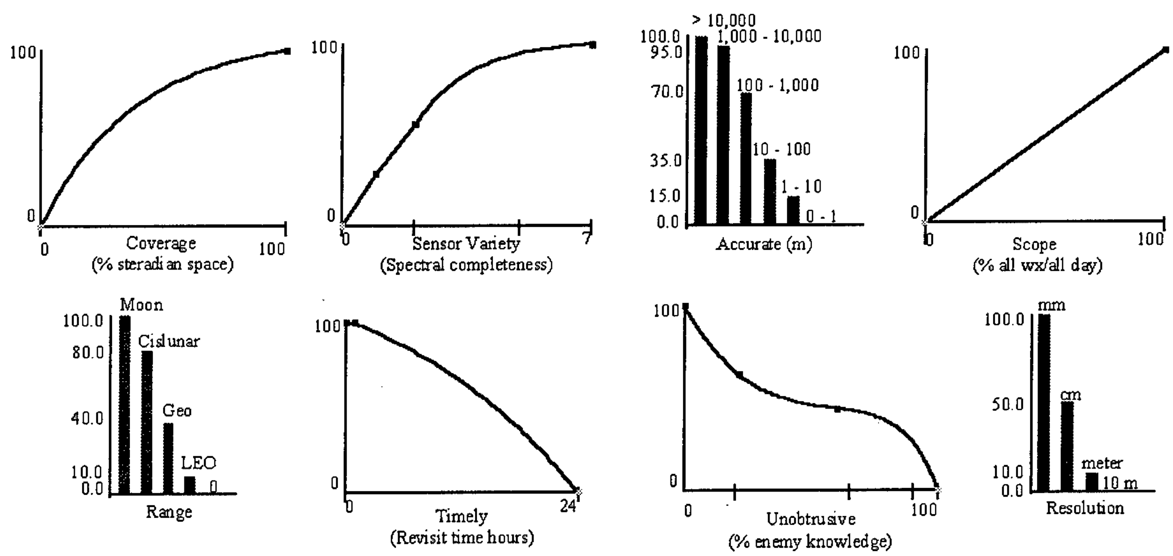


Figure A-6. *Detect in Space* Scoring Functions

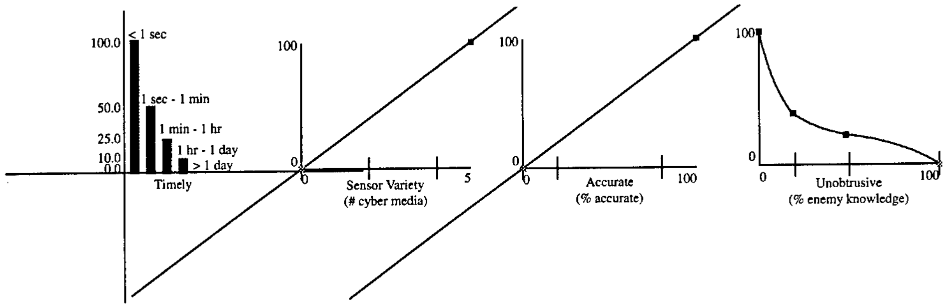


Figure A-7. *Detect in Cyberspace* Scoring Functions

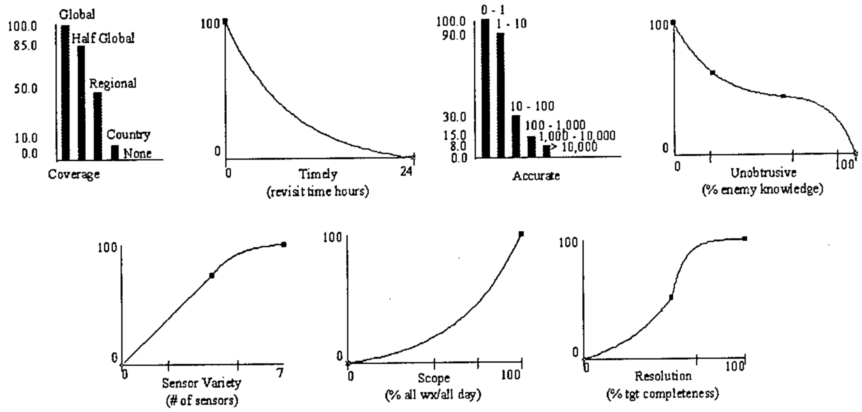


Figure A-8. *Detect on Surface/Subsurface* Scoring Functions

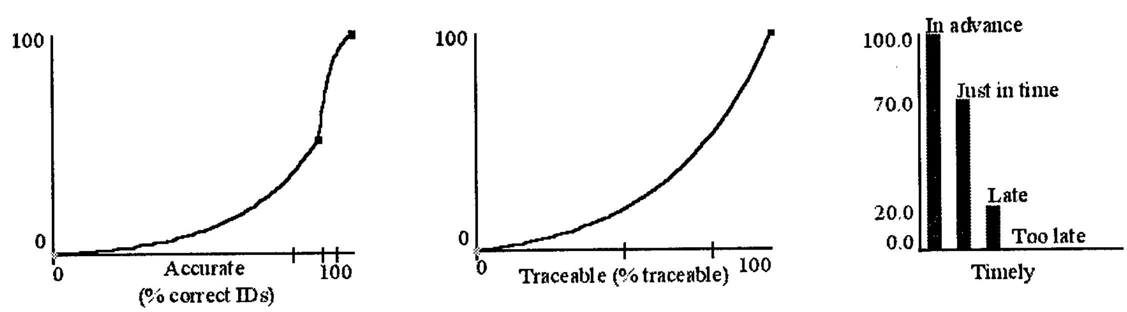


Figure A-9. *Identify* Scoring Functions

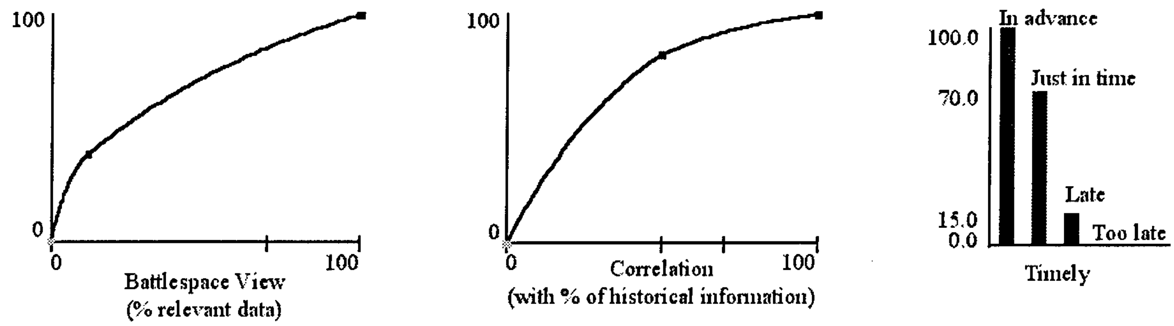


Figure A-10. ***Integrate*** **Scoring Functions**

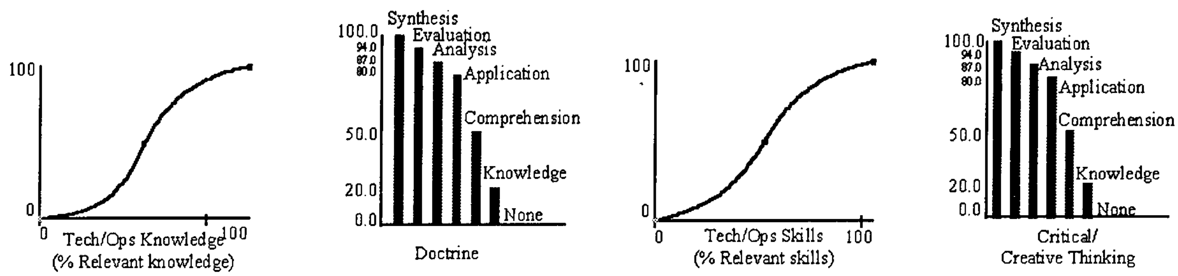


Figure A-11. ***Educate/Train*** **Scoring Functions**

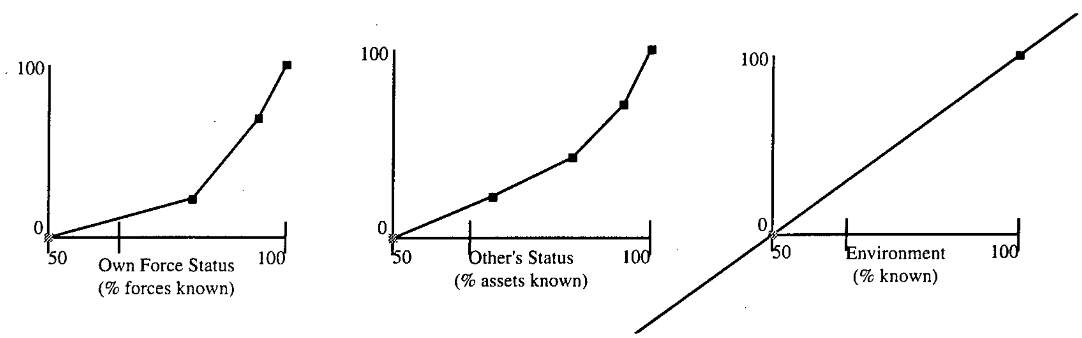


Figure A-12. ***Assess*** **Scoring Functions**

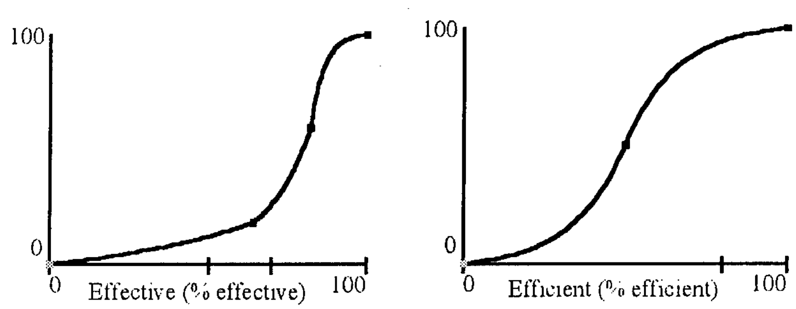


Figure A-13. ***Plan*** **Scoring Functions**

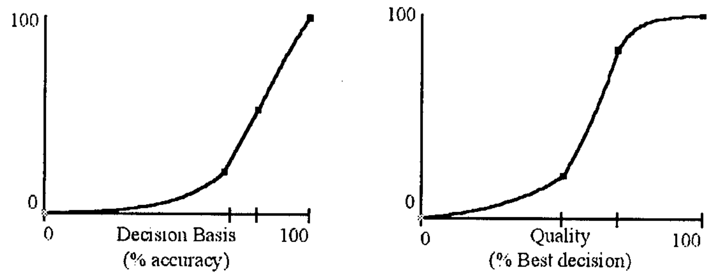


Figure A-14. *Decide* Scoring Functions

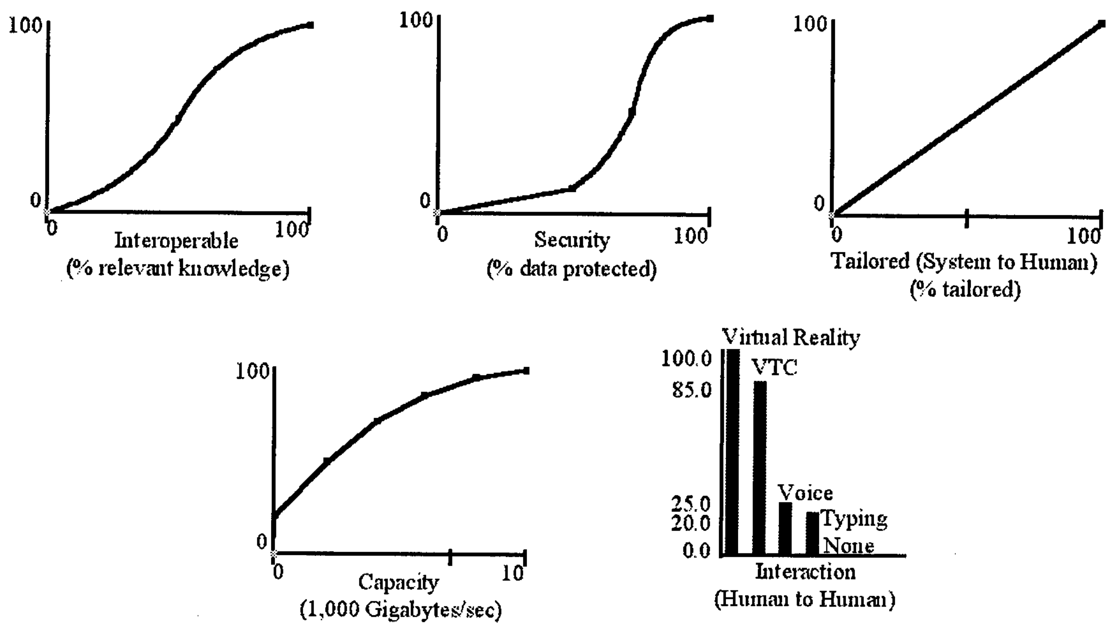


Figure A-15. *Communicate* Scoring Functions

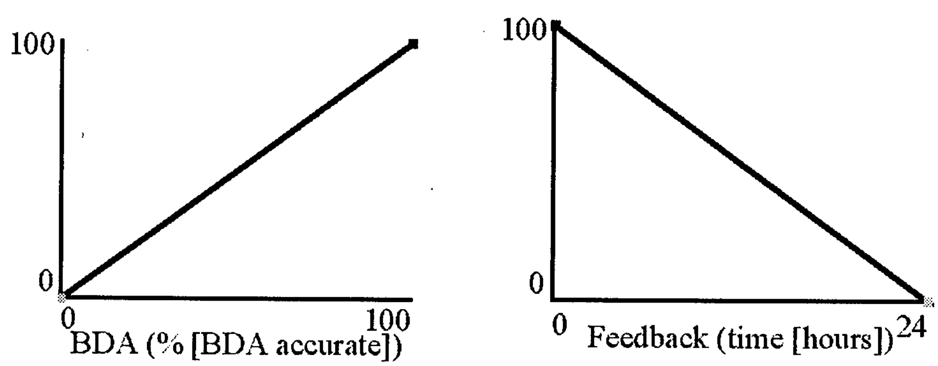


Figure A-16. *Confirm* Scoring Functions

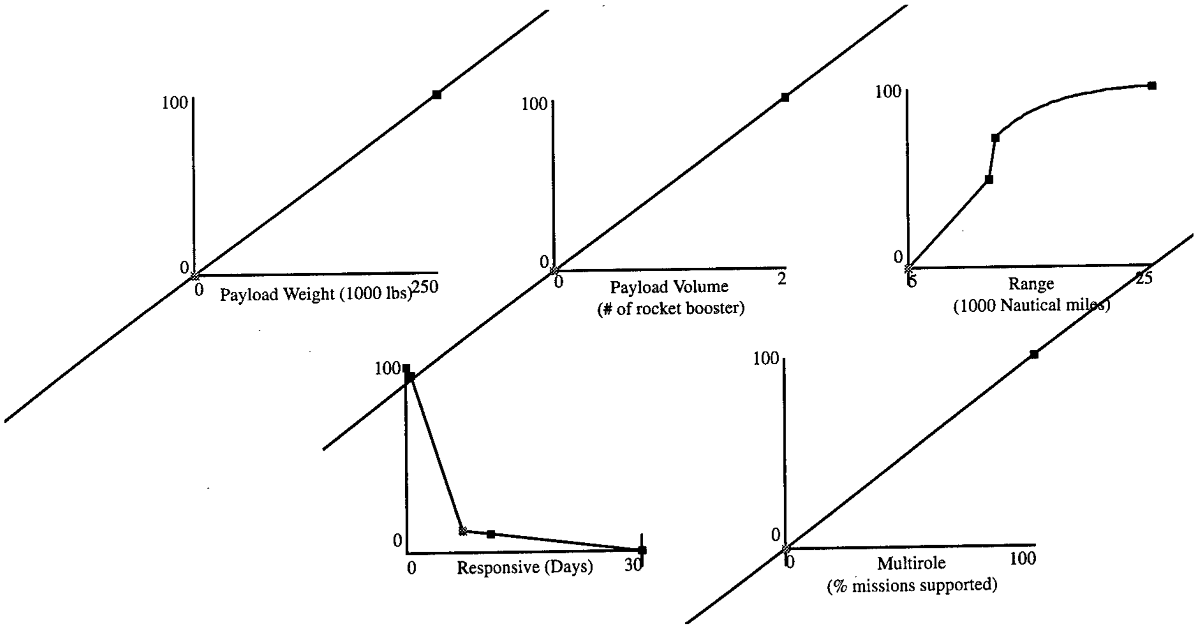


Figure A-17. *Deploy to Air* Scoring Functions

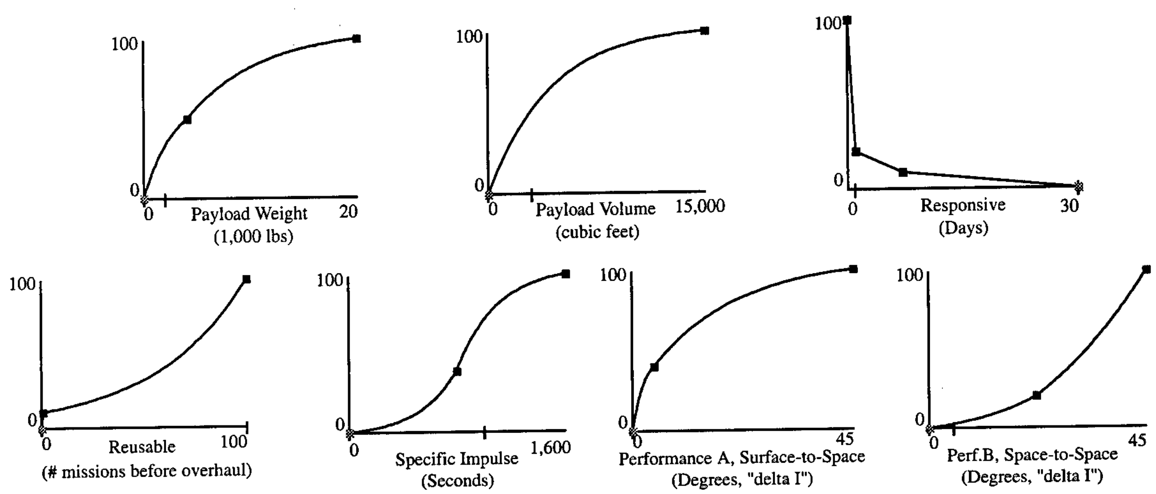


Figure A-18. *Deploy to Space* Scoring Functions

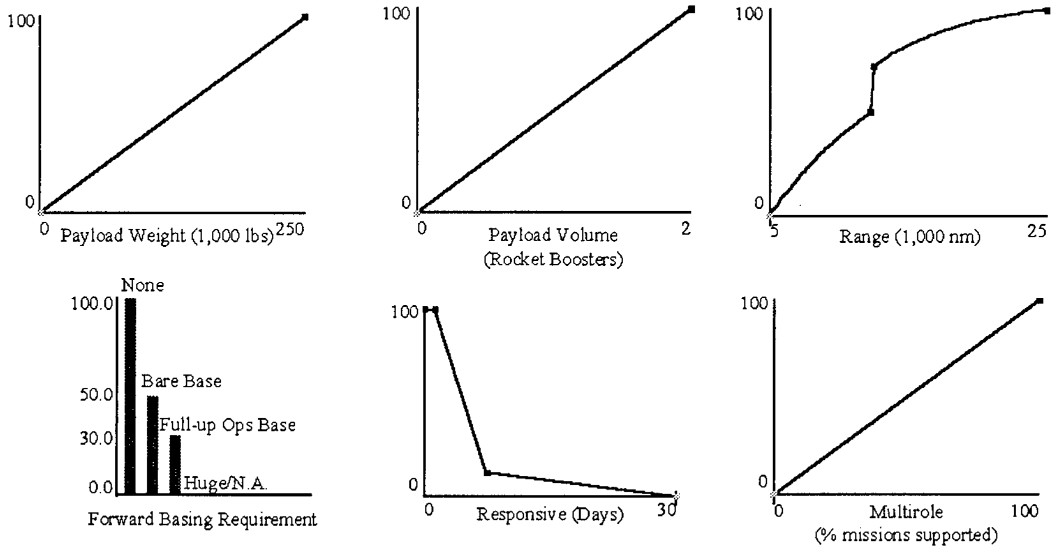


Figure A-19. ***Deploy to Surface*** **Scoring Functions**

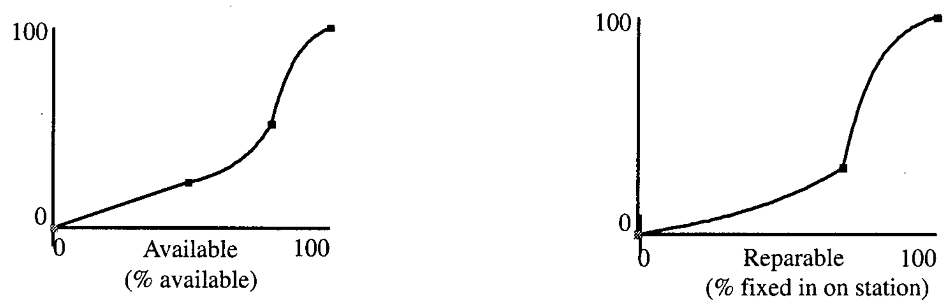


Figure A-20. ***Readiness*** **Scoring Functions**

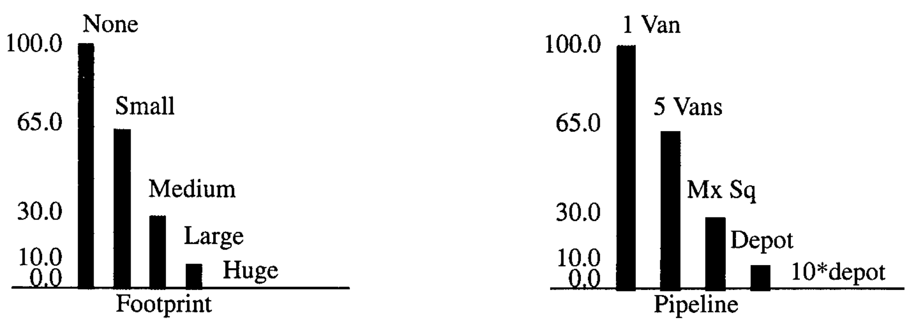


Figure A-21. ***Sustain*** **Scoring Functions**

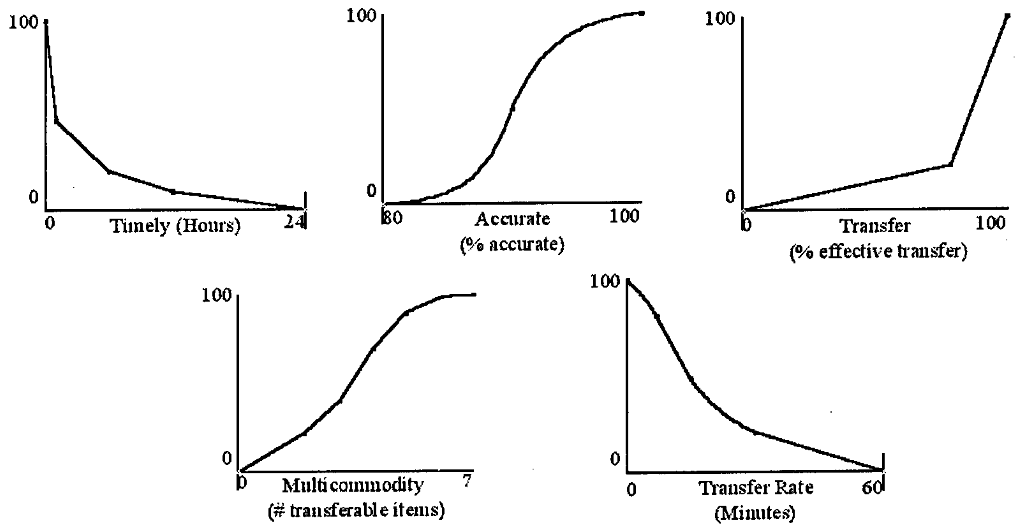


Figure A-22. ***Replenish in Air*** **Scoring Functions**

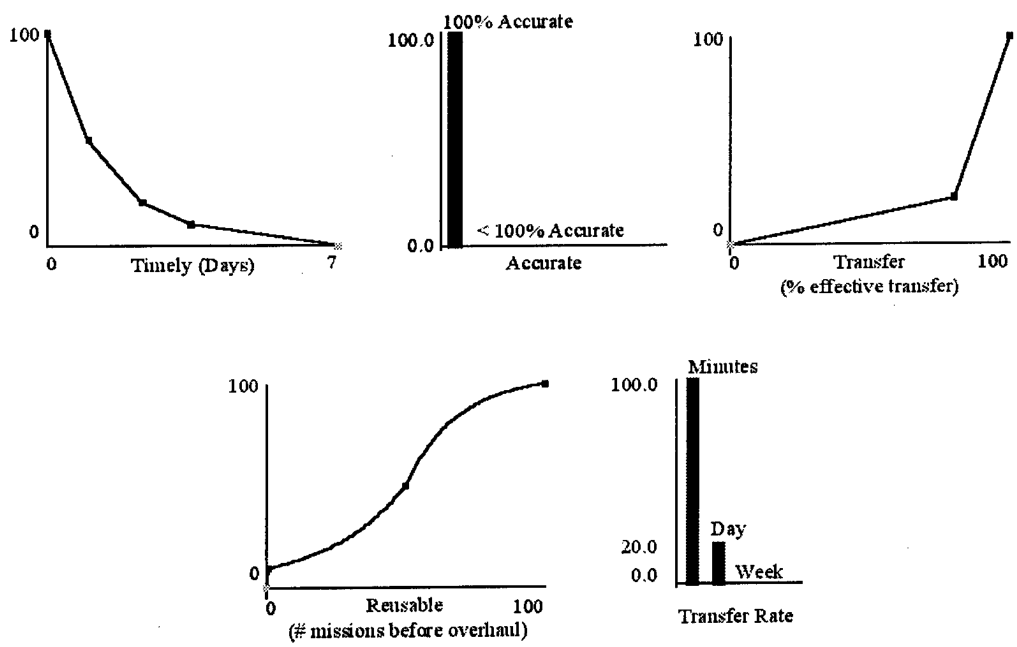


Figure A-23. ***Replenish in Space*** **Scoring Functions**

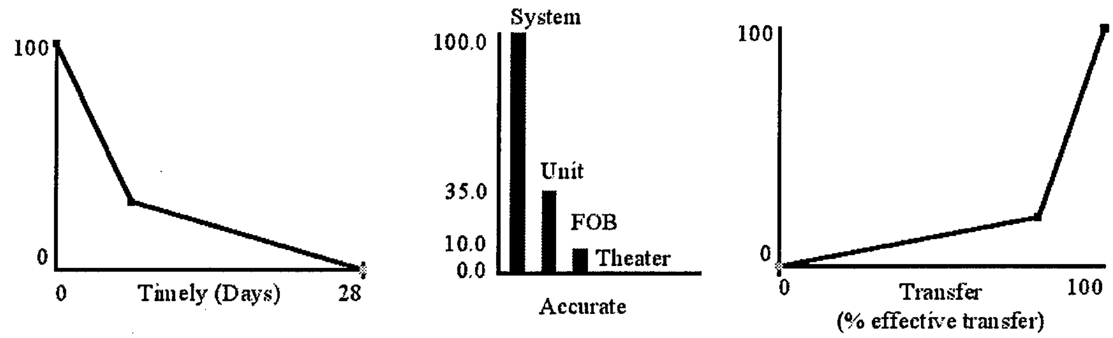


Figure A-24. *Replenish on Surface* Scoring Functions

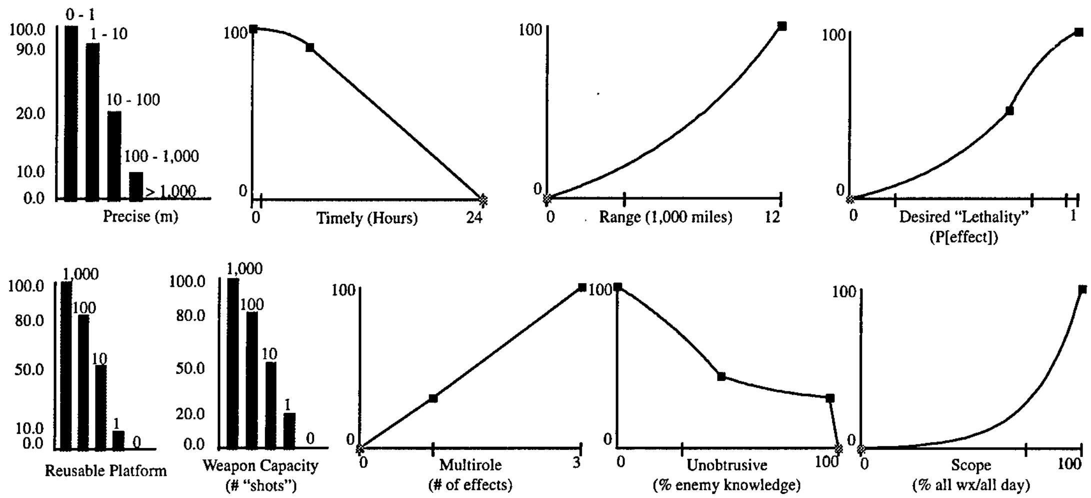


Figure A-25. *Engage in Air* Scoring Functions

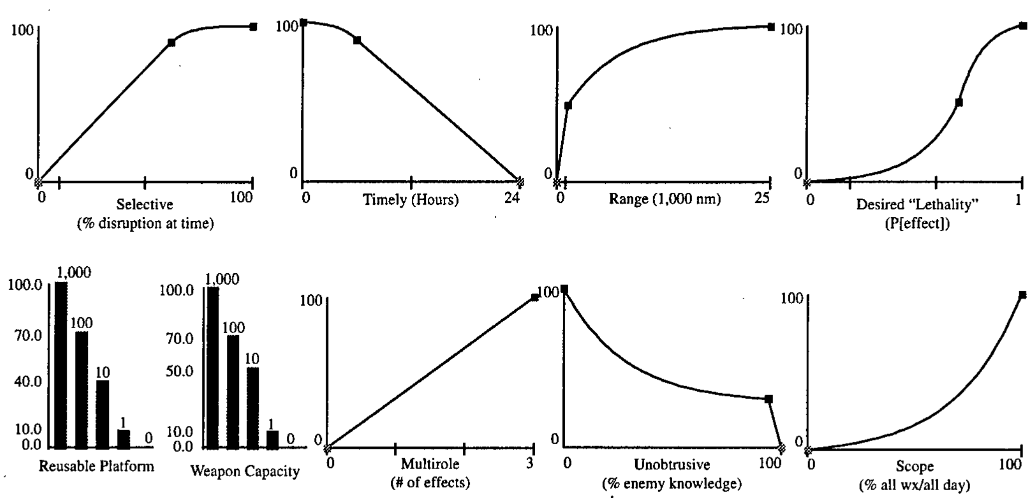


Figure A-26. *Engage in Space* Scoring Functions

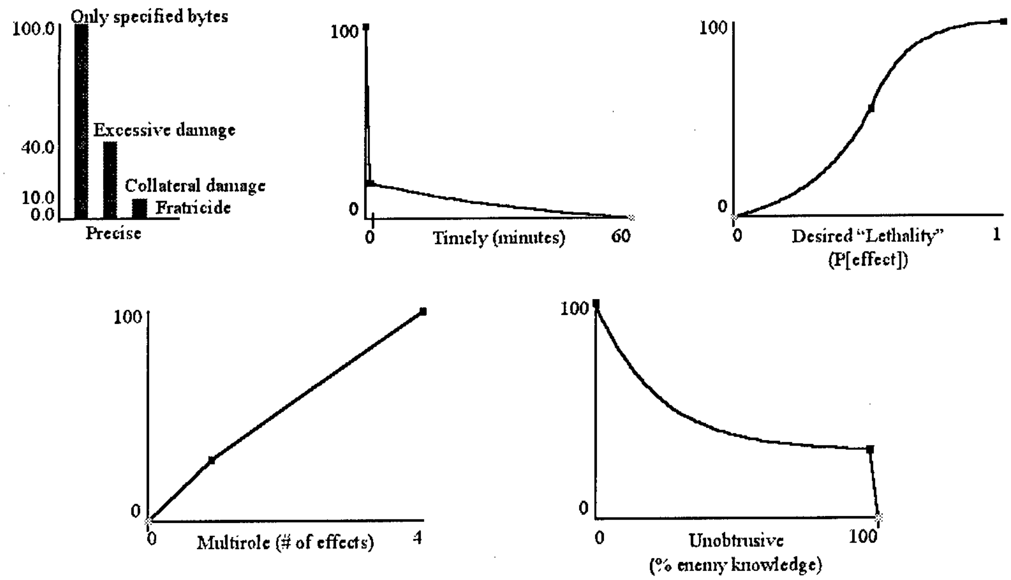


Figure A-27. *Engage in Cyberspace* Scoring Functions

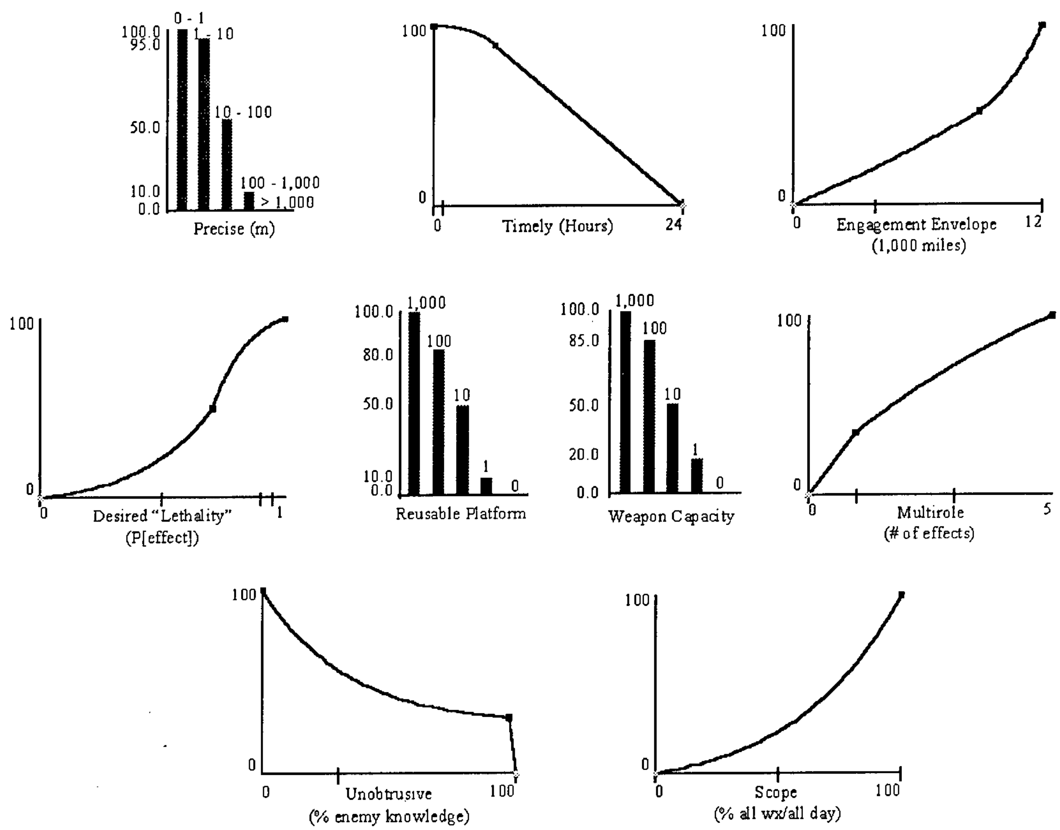


Figure A-28. *Engage on Surface/Subsurface* Scoring Functions

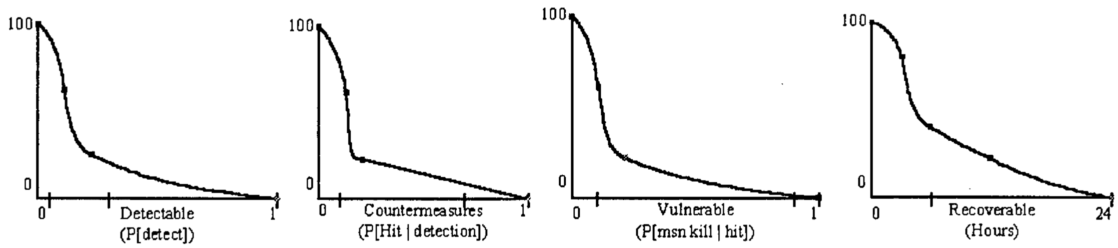


Figure A-29. *Survive in Air* Scoring Functions

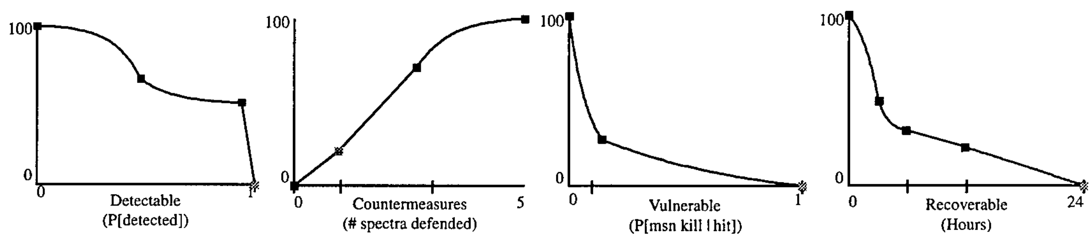


Figure A-30. *Survive in Space* Scoring Functions

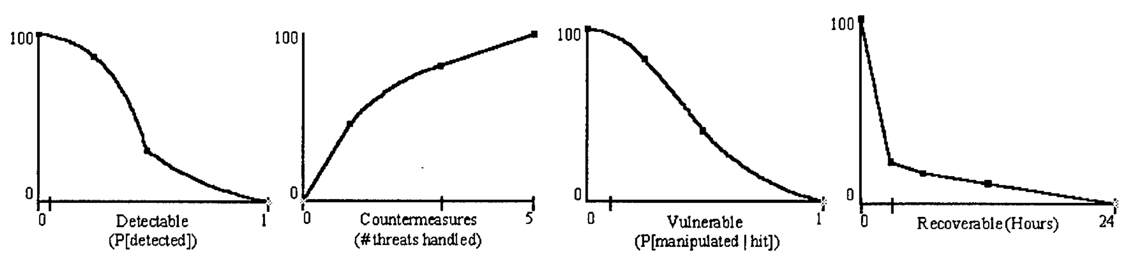


Figure A-31. *Survive in Cyberspace* Scoring Functions

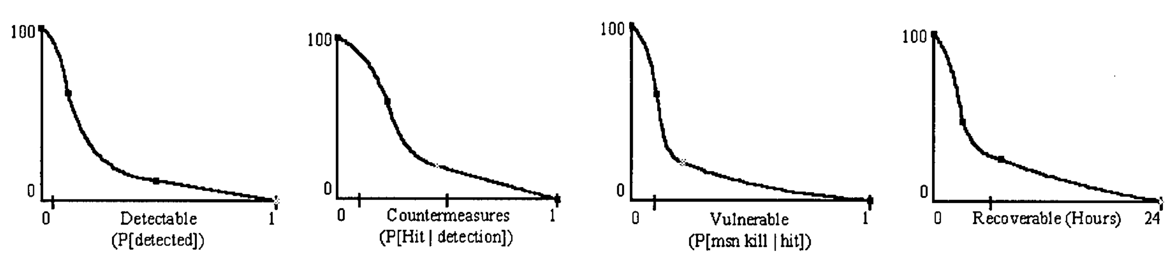


Figure A-32. *Survive on Surface* Scoring Functions

Operational Analysis Glossary

Air - 1. b. This mixture with varying amounts of moisture, low-altitude pollutants, and particulate matter, enveloping the earth: atmosphere.[1]

[Awareness] Aware - 1. Having knowledge or cognizance. 2. Vigilant: watchful.[2]

Appreciate - 1. To recognize the quality, significance, or magnitude of.[3]

Assess - 1. To estimate the value of. 4. To appraise or evaluate.[4]

Command - 1. To give orders to: direct. 2. To have authoritative control over: rule.[5]

Command - 2. An order given by a commander; that is, the will of the commander expressed for the purpose of bringing about a particular action.[6]

Communicate - 1. To have an interchange, as of ideas or information. 2. To express oneself effectively.[7]

Communications - A method or means of conveying information of any kind from one person or place to another.[8]

Control - 1. To exercise authority or influence over: direct.[9]

Control - 1. Authority which may be less than full command exercised by a commander over part of the activities of subordinate or other organizations.[10]

Cyberspace - The virtual space of computer memory and networks, telecommunications and digital media.[11]

Decide - 1. To pronounce a judgment. 2. To make up one's mind.[12]

Decision - In an estimate of the situation, a clear and concise statement of the line of action intended to be followed by the commander as the one most favorable to the successful accomplishment of his mission.[13]

Deploy - 1. To station (persons or forces) systematically over an area.[14]

Deployment - 3. In a strategic sense, the relocation of forces to desired areas of operation.[15]

Detect - 1. To discover or discern the existence, presence, or fact of.[16]

Detection - The discovery by any means of the presence of a person, object, or phenomenon of potential military significance.[17]

Educate - 1. a. To provide with training or knowledge, esp. via formal schooling: teach. b. To provide with training for a specific purpose, as a vocation. 2. To provide with information: inform. 3. To stimulate or develop the mental or moral growth of.[18]

Employ - 1. To put to service or use. 2. To apply or devote (e.g., time) to an activity. 3. a. To put to work.[19]

Engage - 1. To obtain or contract for the services of: employ. 2. To contract for the use of : reserve. 3. To obtain and hold the attention of: engross. 4. To require the use of: occupy. 6. To enter or bring into conflict with. To interlock or cause to interlock: mesh. 8. To win: attract. 9. To involve: entangle.[20]

Engage - In air intercept, a code meaning, "Attack designated contact."[21]

Global - 2. Of, pertaining to, or involving the entire earth: worldwide. 3. Total: comprehensive.[22]

Global Awareness - The ability to use affordable means to derive appropriate information about one or more places of interest after a delay which is short enough to satisfy operational needs.[23]

Identify - 1. b. To find out the origin, nature, or definitive elements of.[24]

Identification - 1. The process of determining the friendly or hostile character of an unknown detected contact.[25]

Imbue - 2. To inspire, permeate, or pervade.[26]

Integrate - 1. To make into a whole by bringing all parts together: unify. 2. To join with something else: unity.[27]

Maintain - 2. To preserve or keep in a given existing condition, as of efficiency or good repair. 3. a. To provide for. b. To keep in existence: sustain.[28]

Maintenance - 1. All action taken to retain materiel in or to restore it to a specified condition. It includes: inspection, testing, servicing, classification as to serviceability, repair, rebuilding, and reclamation. 2. All supply and repair action taken to keep a force in condition to carry out its mission. 3. The routine recurring work required to keep a facility (plant, building, structure, ground facility, utility system, or other real property) in such condition that it may be continuously utilized, at its original or designed capacity and efficiency, for its intended purpose.[29]

Plan - 1. To formulate a scheme or program for the accomplishment or attainment of.[30]

Power - 1. The ability or capacity to act or perform effectively. 3. Strength or force exerted or capable of being exerted: might. 4. The ability or official capacity to exercise control over others. 5. A person, group, or nation having great influence or control over others. 6. The might of a nation, political organization, or similar group.[31]

Prepare - To make ready in advance for a particular purpose, event, or occasion.[32]

Reach - 1. The act or power of stretching or thrusting out. 2. The distance or extent something can reach. 3. b. The range or scope of influence or effect.[33]

Replenish - To fill or make complete again: add a new supply to.[34]

Space - 2. The expanse in which the solar system, stars, and galaxies exist: universe.[35]

Subsurface - Below, under, beneath the surface.[36]

Surface - 2. b. The two-dimensional locus of points located in three-dimensional space whose height z above each point (x,y) of a region of a coordinate plane is specified by a function $f(x,y)$ of two arguments.[37]

Survive - 1. To remain alive or in existence. 2. To persist through.[38]

Train - 1. To coach in or accustom to a mode of behavior or performance. 2. To make proficient with special instruction and practice.[39]

Understand - 1. To perceive and comprehend the nature and significance of.[40]

Notes

1. *Webster's II New Riverside University Dictionary.*
2. Ibid.
3. Ibid.
4. Ibid.
5. Ibid.
6. DOD; IADB; and *JCS Pub 1.*
7. *Webster's Dictionary.*
8. DOD; IADB; and *JCS Pub 1.*
9. *Webster's Dictionary.*
10. DOD; IADB; and *JCS Pub 1.*
11. Bob Cotton, *The Cyberspace Lexicon: An Illustrated Dictionary of Terms from Multimedia to Virtual Reality* (London: Phaedon, 1994).
12. *Webster's Dictionary.*
13. DOD; IADB; and *JCS Pub 1.*
14. *Webster's Dictionary.*
15. NATO; DOD; IADB; and *JCS Pub 1.*
16. *Webster's Dictionary.*
17. NATO; and *JCS Pub 1.*
18. *Webster's Dictionary.*
19. Ibid.
20. Ibid.
21. DOD; and *JCS Pub 1.*
22. *Webster's Dictionary.*
23. USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century,* summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995).
24. *Webster's Dictionary.*
25. DOD; IADB; and *JCS Pub 1.*
26. *Webster's Dictionary.*
27. Ibid.
28. Ibid.
29. NATO; and *JCS Pub 1.*
30. *Webster's Dictionary.*
31. Ibid.
32. Ibid.
33. Ibid.
34. Ibid.
35. Ibid.
36. Ibid.
37. Ibid.
38. Ibid.
39. Ibid.
40. Ibid.

Appendix B

System Descriptions

This appendix provides a description of each of the 43 systems identified in the ***2025*** study. Figure B-1 shows the system hierarchy, categorized by functional area. Each system description contains a brief narrative, a list of capabilities, enabling technologies, and ***2025*** white papers relating to the system. Table 4 lists the ***2025*** student writing teams.

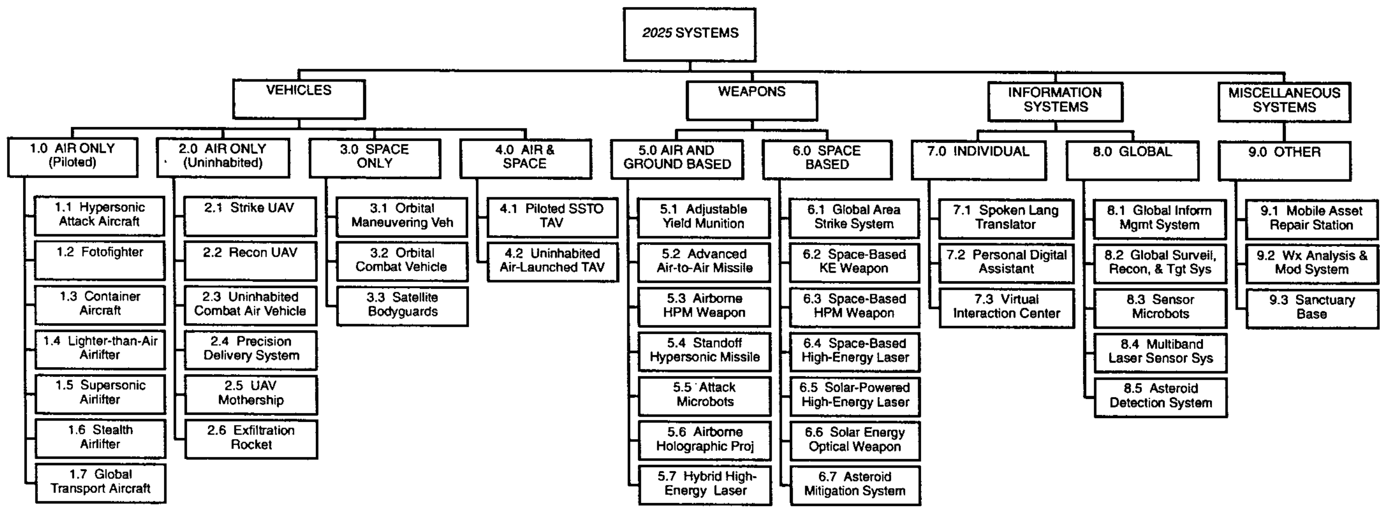


Figure B-1. System Hierarchy

Table 4

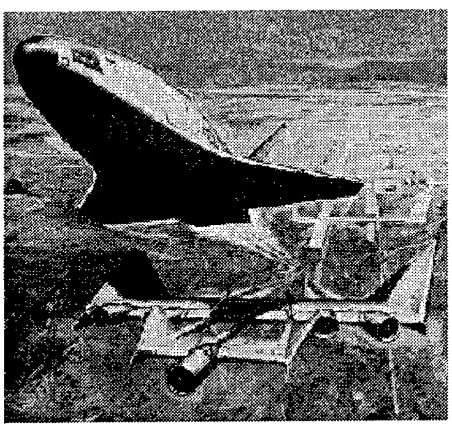
Writing-Team Letter Designators and Names

A	Counterair
B	Planetary Defense
C	Counterspace
D	Operability and Defense
E	Counterinformation
F	Airlift
G	Spacelift
H	Aerospace Replenishment
I	Frontier Missions
J	Close Air Support
K	Interdiction
L	Strategic Aerospace Warfare Study
M	Information Operations
N	Strategic Attack
O	C^2 Attack
P	Strategic & C^2 Attack
Q	Special and Humanitarian Operations
R	Special Operations
S	RPV & Aerospace
T	Space Surveillance & Reconnaissance Fusion
U	Surveillance & Reconnaissance Information Operations
V	Surveillance & Reconnaissance Real Time Integration
W	On-Orbit Support
X	General Education & Training
Y	Training & Readiness
Z	Information Technology Integration in Education & Training
β	USAFA Information Technology Management
Δ	Space Operations
Φ	Logistics
Γ	Weather Modification
Λ	Alternate Futures
Π	AFIT Operational Analysis
Θ	Combat Support
Σ1	AFIT Space Operations
Σ2	AFIT Space Operations
Ω	AFIT Logistics
Ψ1	USAFA Hypersonics
Ψ2	USAFA Hypersonics
Ψ3	USAFA Hypersonics

1.1 Hypersonic Attack Aircraft

Brief Description

A high-speed strike vehicle capable of projecting lethal force anywhere in the world in less than four hours. Operating at Mach 12 and a cruise altitude of 100,000 feet, this vehicle is a reusable two-stage system comprised of an unmanned boost vehicle and a manned hypersonic strike aircraft. The gas turbine boost vehicle requires a conventional runway and accelerates the strike vehicle to Mach 3.5 and 65,000 feet. The strike vehicle then separates and uses a Ramjet/supersonic combustion Ramjet (Scramjet) engine to reach its cruise condition. The total system range is 10,000 NM; the hypersonic strike vehicle has an unrefueled range of 5,000 NM. It is capable of launching precision guided munitions, including the hypersonic air-to-ground missile described in system 5.4, at a standoff distance of 1,450 NM. Alternatively, the platform may be used to transport an uninhabited UAV described in system 4.2.



Capabilities

- Weapons suite includes precision guided munitions including up to 10 standoff hypersonic missiles
- Designed to transport an uninhabited TAV to 100,000 ft
- Requires turbine-engined supersonic launch platform to achieve operating condition

Enabling Technologies (MCTL)

- 1.0, Materials
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 9.2, Ramjet, Scramjet, and Combined Cycle Engines
- 9.5.4, Aerospace Structures and Systems
- 12.7, Energetic Materials

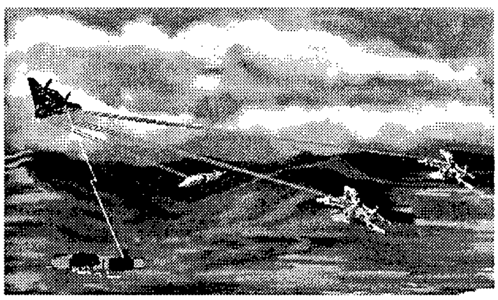
White Papers

- Ψ, Hypersonics

1.2 Fotofighter

Brief Description

A highly maneuverable, stealthy, inhabited advanced fighter aircraft whose skin is fitted with an array of diode lasers and sensors. Efficient electronic control of the laser arrays allows this fighter to engage multiple targets simultaneously with varying degrees of lethality. At low powers, the arrays can function as transmitters and receivers for low probability of intercept (LPI) communications. Threat detection, target illumination, and tracking are also possible.



Capabilities

- Automatic threat detection, tracking, and target illumination
- Transmitter and receiver for LPI communications
- Energy replenishment for directed energy weapons (DEW) armament from other air/ground DEW platforms while airborne

Enabling Technologies (MCTL)

- 1.0, Materials
- 2.6, Micromechanical Devices (MEMS)
- 9.5, Aerospace Structures and Systems
- 4.1, Digital Computing
    - 4.1.1, High-Performance Computing
- 4.2.5, Data Fusion
- 4.3, Hybrid Computing
- 6.0, Sensors and Electronic Combat Technology
    - 6.2, Optical Sensors
    - 6.8, Radar Sensors
- 10.1, Lasers
- 11.1, High-Energy Laser (HEL) Systems

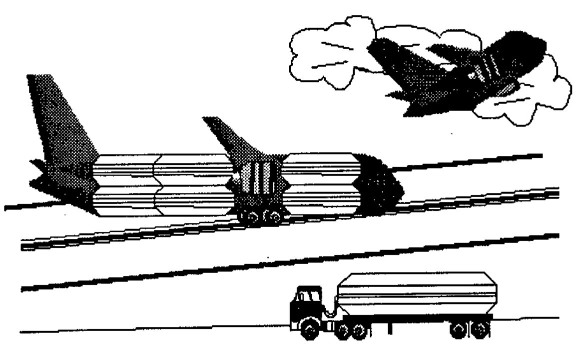
White Papers

- A, Counterair

1.3 Container Aircraft

Brief Description

The container aircraft consists of an airlifter in which standard shipping containers would form integral structures of the fuselage. The aircraft consists of three baseline sections: (1) the cockpit, (2) the wingbox, and (3) the empennage. In its simplest form, the "short" version, the aircraft is capable of flight by joining the cockpit, wingbox, and empennage directly together. With standard shipping containers installed between the cockpit and wingbox, the wingbox and the empennage, the aircraft would be configured to carry cargo ("stretch" version). The first wave of container aircraft to arrive in a theater of operations would be "disassembled." The cockpit would form a command and control facility, the aircraft engines would generate the base power, the wings could provide fuel storage, and the containers themselves (when empty) would provide shelter for troops, supplies, and equipment. This concept will provide a mobile base.



Capabilities

- Modular aircraft using "standardized" modular cargo containers as integral fuselage components
- Provides intertheater airlift of troops, supplies, equipment and MEDVAC
- When disassembled at a bare base, provides mobile base facilities
- C³I center (cockpit), power station (engines), fuel storage (wings), base buildings (empty containers)

Enabling Technologies (MCTL)

- 1.0, Materials
- 7.3, Vehicle and Flight Control
- 9.5, Aerospace Structures and Control
- 9.5.4, Aircraft High-Performance Structures

White Papers

- Ω, AFIT Logistics

1.4 Lighter-than-Air Airlifter

Brief Description

A large capacity, rigid-frame, lighter-than-air vehicle that provides 1-million-pound airlift capability with an unrefueled range of 12,500 NM. This vehicle would also have the ability to deploy and recover powered UAVs while stationary or in-transit. Vehicle is able to house support materiel, personnel and MEDVAC modules depending upon mission requirements.

Capabilities

- Global transport of 1 million pounds of materiel, equipment and personnel to/from bare bases in theater
- Deploy and recover UAVs while airborne
- Transport and house MEDEVAC modules

Enabling Technologies (MCTL)

- 1.0, Materials
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 7.3, Vehicle and Flight Control
- 9.5.4, Aircraft High-Performance Structures

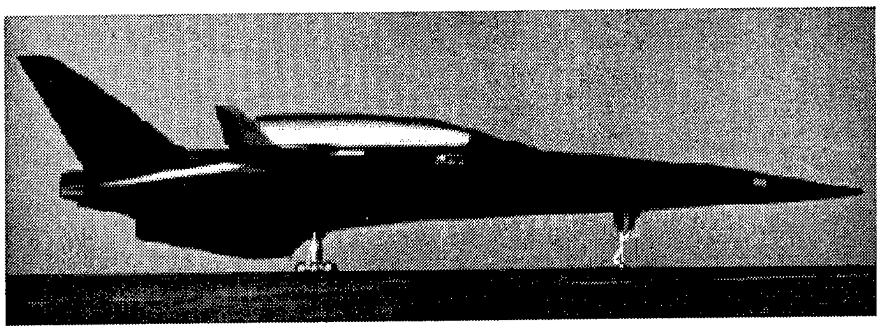
White Papers

- F, Airlift

1.5 Supersonic Airlifter

Brief Description

A Mach 2.4 supersonic airlifter that provides 50,000-pound airlift capability with an unrefueled range of 5,000 NM. This vehicle would provide the capability to deliver military personnel (roughly 150), advanced precision weapons, and appropriate resupply worldwide within hours.



Capabilities

- Rapid global transport of personnel and support materiel
- Mach 2.4 cruise speed with a payload of 50,000 pounds; unrefueled range of 5,000 NM

Enabling Technologies (MCTL)

- 1.0, Materials
- 2.6, Micromechanical Devices (MEMS)
- 9.5.4, Aircraft High-Performance Structures
- 9.1, Gas Turbine Propulsion Systems
- 4.1, Digital Processing
    - 4.1.1, High-Performance Computing

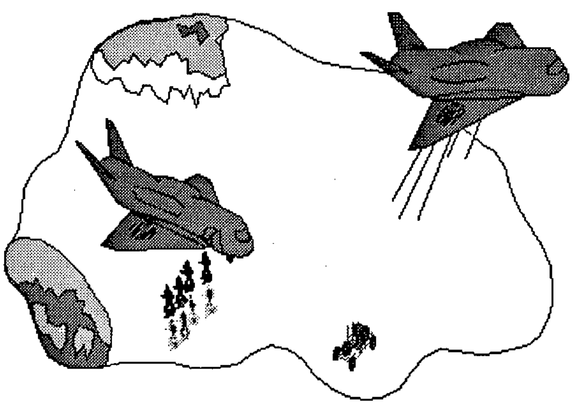
White Papers

- F, Airlift

1.6 Stealth Airlifter

Brief Description

The stealth airlifter (SA) is an all-weather, low observable, aircraft capable of low-supersonic cruise and dedicated to special operations forces (SOF). With an unrefueled range up to 4,000 NM, it would be used for insertion and extraction of SOF teams, as well as for extraction of high-value assets (HVA) and weapons of mass destruction. The SA would be connected to a global information management system (e.g., GIMS System 8.1), for all source intelligence, weather, navigation, and communications.



Capabilities

- Capable of operating from in-theater operating bases; all-weather, low observable, supersonic cruise aircraft designed to support SOF missions
- Vertical/short take off and landing (V/STOL) capable
- Can transport 2,500 pounds up to 4,000 NM

Enabling Technologies (MCTL)

- 1.0, Materials
- 9.1, Gas Turbine Propulsion Systems
- 9.5.4, Aircraft High-Performance Structures

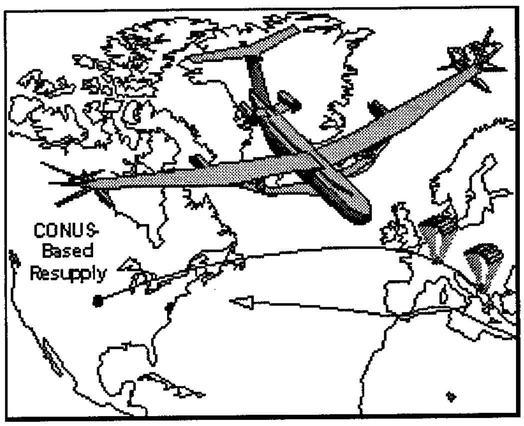
White Papers

- R, Special Operations

1.7 Global Transport Aircraft

Brief Description

A global reach transport airplane of less than 1 million pounds take-off gross weight, capable of carrying 150,000–250,000 pounds 12,000 to 10,000 NM, respectively. This vehicle also would have the ability to deploy powered UAVs and parafoils. The GTA would be able to house support materiel, personnel, and MEDVAC modules depending upon mission requirements. This aircraft also could be modified for use as a tanker.



Capabilities

- Payload: 150,000–250,000 lbs
- Unrefueled Range: 10,000–12,000 NM
- Can deploy powered UAVs and parafoils for precision delivery
- Can be reconfigured for air refueling and MEDEVAC

Enabling Technologies (MCTL)

- 1.0, Materials
- 9.1, Gas Turbine Propulsion Systems
- 9.5, Aerospace Structures and Systems
    - 9.5.4, Aircraft High-Performance Structures

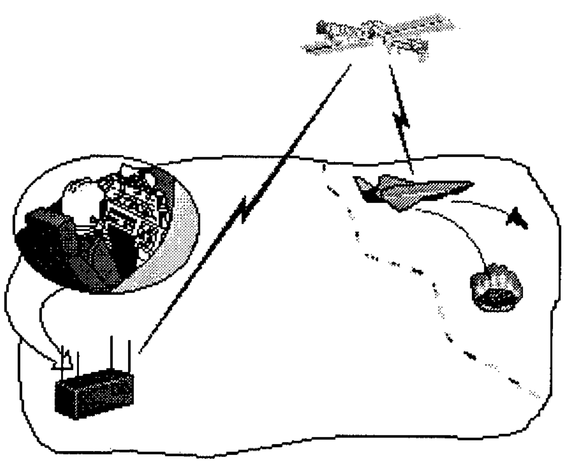
White Papers

- F, Airlift

2.1 Strike UAV

Brief Description

The Strike UAV is a low observable, uninhabited air vehicle that loiters subsonically over the region of interest for long periods of time (24+ hours) until directed to strike. Its primary mission is to engage ground targets with standoff precision munitions; however, it also has a limited air-to-air capability. It relies on off-board sensors to supply reconnaissance and targeting information as well as command and control, although it has sufficient on-board sensor capability to allow it to perform preprogrammed missions.



Capabilities

- Subsonic, low observable, long-loiter time (24+ hour) strike capability
- Employs a suite of precision guided munitions
- Air to ground, limited air to air
- Uses primarily off-board sensors
- Capable of operating from in-theater operating bases

Enabling Technologies (MCTL)

- 1.0, Materials
- 4.1, Digital Processing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.5, Data Fusion
- 5.4, Command, Control, Communications, and Intelligence Systems
- 5.5, Information Security
- 9.8, Other Propulsion
- 12.1, Warheads, Ammunition, and Payloads

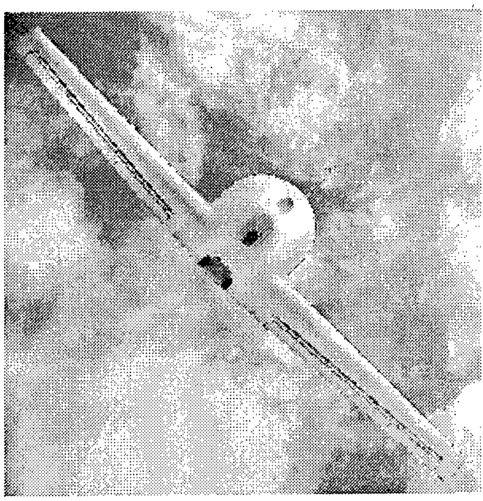
White Papers

- A, Counterair
- S, RPV and Aerospace

2.2 Reconnaissance UAV

Brief Description

The uninhabited reconnaissance aerial vehicle (URAV) can be employed either as an independent system or in conjunction with other airborne, ground-based, and space-borne systems. The URAV is fitted with a variety of multispectral sensors, such as infrared, optical, and radar and laser, and collects images, SIGINT, ELINT, and other information. It loiters subsonically at high altitudes over the region of interest for extended periods of time without refueling. The URAV could also be used as part of a bistatic configuration, in which it illuminates the region of interest, while different sensors then receive and process the information.



Capabilities

- High-altitude, long-loiter times (36+ hours)
- Gathers information from multi-spectral sensors, feeds into Global Information Management System

Enabling Technologies (MCTL)

- 1.0 Materials
- 4.1 Digital Processing
  - 4.1.3 Signal Processing
  - 4.1.4 Image Processing
- 4.2 Software
  - 4.2.5 Data Fusion
- 5.1 Transmission
- 6.2 Optical Sensors
- 6.8 Radar
- 6.9 Other Sensors
- 10.3 Power Systems

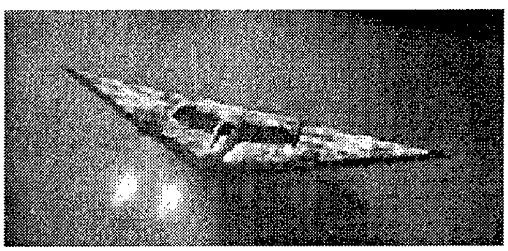
White Papers

- U, S&R Info Ops
- J, Close Air Support

2.3 Uninhabited Combat Air Vehicle

Brief Description

The uninhabited combat air vehicle (UCAV) can be employed either as an independent system or in conjunction with other airborne, ground-based, and space-based systems. It carries a suite of multispectral sensors (optical, infrared, radar, and laser) which supplies information to its suite of standoff precision guided munitions. It loiters at high altitude over the region of interest for long periods of time (24+ hours) until called upon to strike a target. While in its subsonic loiter mode, it can perform a surveillance and reconnaissance mission for the global information management system (System 8.1). It could be used as part of a bistatic configuration in which it illuminates a region of interest while a different sensor receives and processes the information. As a secondary mission, it can perform ECM and electronic counter-countermeasures (ECCM) roles.



Enabling Technologies (MCTL)

- 1.0, Materials
- 4.1, Digital Processing
  - 4.1.3, Signal Processing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.5, Data Fusion
  - 4.2.9, Artificial Intelligence
- 5.5, Information Security
- 6.2, Optical Sensors
- 6.8, Radar
- 6.9, Other Sensors
- 9.8, Other Propulsion
- 10.3, Power Systems
- 12.1, Warheads, Ammo, & Payloads

White Papers

- A, Counterair
- J, Close Air Support
- S, RPV and Aerospace

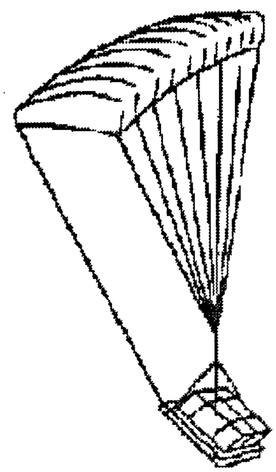
Capabilities

- Subsonic, low observable, long-loiter (24+ hour) reconnaissance and strike capability
- Uses multispectral sensors to employ a suite of precision guided munitions
- Sensors can also feed into the Global Information Management System
- Extensive air-to-ground and air-to-air capability
- Secondary role as ECM and ECCM platform

2.4 Precision Delivery System

Brief Description

A suite of powered and parafoil UAVs capable of autonomous flight for the purpose of all-weather precision airdrop (within 1 meter). High-altitude (40,000 ft) precision airdrops can be achieved using GPS or INS-guided parafoil delivery systems. This technique would allow equipment/supplies to be delivered to forward deployed forces while transport aircraft remain hundreds of miles from the drop zone. Positions can be determined using LIDAR or a GPS instrumented radio drop sound. Powered UAVs would deliver smaller, high-value packages from greater standoff ranges.



Capabilities

- Precision delivery of equipment or supplies to within one meter accuracy on the ground from 150 NM range
- Uses passive GPS/INS sensors to enhance survivability

Enabling Technologies (MCTL)

- 1.0, Materials Technology
- 2.6, Micromechanical Devices (MEMS)
- 7.3, Vehicle and Flight Control
- 7.1, Inertial Navigation Systems and Related Components
    - 7.1.1, Inertial Navigation Systems
    - 7.1.10, Accelerometers

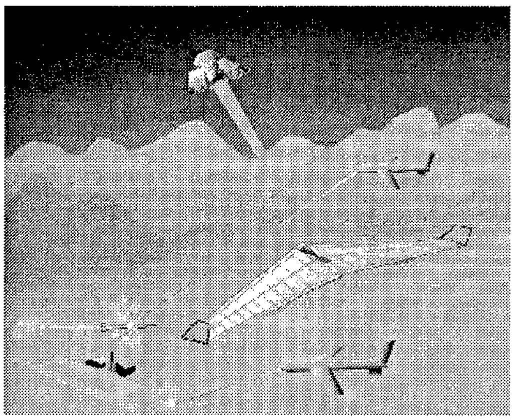
White Papers

- F, Airlift
- Q, Special and Humanitarian Operations
- R, Special Operations
- I, Frontier Missions

2.5 UAV Mothership

Brief Description

A large-capacity, long-loiter time, uninhabited subsonic air vehicle used to deploy and recover smaller combat UAVs. It also can replenish them with weapons and propellant. This air vehicle would have the ability to collect, convert, and store solar energy and then transfer energy through physical means or by way of beaming to other airborne vehicles, including the Fotofighter (System 1.2).



Capabilities

- A long-loiter air vehicle used to deploy, recover and replenish UAVs
- Uses DEW to serve as a rearming platform for the "Fotofighter"

Enabling Technologies (MCTL)

- 1.0, Materials
- 2.2, Metal Working and Industrial Production
  - 2.2.5, Robots, Controllers, and End-Effectors
- 9.5.4, Aircraft High-Performance Structures
- 10.1, Lasers
- 10.2, Optics
- 10.3, Power systems
- 11.1, High-Energy Laser (HEL) Systems

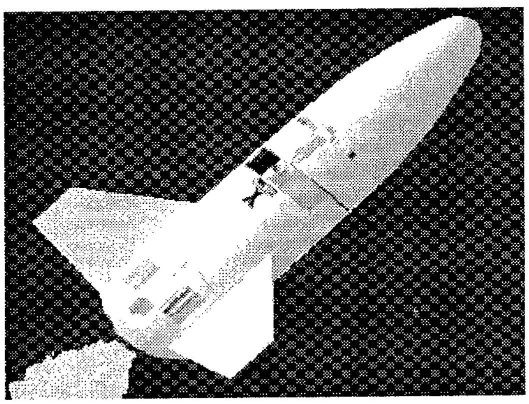
White Papers

- H, Aerospace Replenishment

2.6 Exfiltration Rocket

Brief Description

The exfiltration rocket (ER) allows a quick extraction of special operations forces teams from the mission area. This system would be brought in during the SOF insertion and assembled at the exfiltration launch site. After mission completion, the SOF team would load themselves and any other items, such as a high-value asset or weapon of mass destruction, into the ER and then take off. The payload and passengers would be recovered by way of an air-retrievable payload system or through a "soft" landing in a friendly area.



Capabilities

- Fast extraction of SOF team from mission area
- 1,000 pounds payload—carries two-four persons, WMD and/or captured high-value asset
- Recovery in air enroute or after soft surface touchdown on friendly ground
- Subsonic speed, 50 NM range, 100 feet CEP

Enabling Technologies (MCTL)

- 1.0, Materials
- 7.3, Vehicle and Flight Control
- 9.5.4, Aerospace Structures and Systems
- 12.7, Energetic Materials

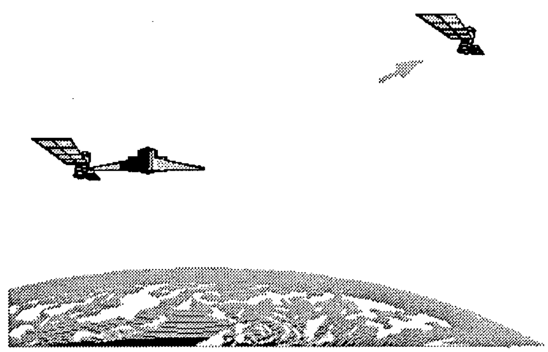
White Papers

- R, Special Operations

3.1 Orbital Maneuvering Vehicle

Brief Description

The orbital maneuvering vehicle (OMV) is an uninhabited orbital propulsion and docking system used to take payloads from an earth-to-orbit lift vehicle and place them in their final orbital plane or used to fetch and return orbiting payloads to a central repair and recovery location. The system also would be capable of carrying line replaceable units (LRU) to a damaged/degraded satellite and accomplishing on-site repair or replacement. It would be designed to allow refueling of civil, commercial, and military satellites as well as the rearming of military space weapons platforms.



Capabilities

- Can maneuver payloads from one earth orbit to another
- Repair of space assets using LRUs
- Refueling of civil, commercial, and military satellites
- Supply/resupply of military space assets

Enabling Technologies (MCTL)

- 2.2, Metal Working and Industrial Production
    - 2.2.5, Robots, Controllers, and End Effectors
- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
    - 4.1.1, High-Performance Computing
- 4.2, Software
    - 4.2.9, Artificial Intelligence
- 9.5, Aerospace Structures and Systems
    - 9.5.2, Nonchemical, High-Specific Impulse Propulsion
- 10.3, Power Systems

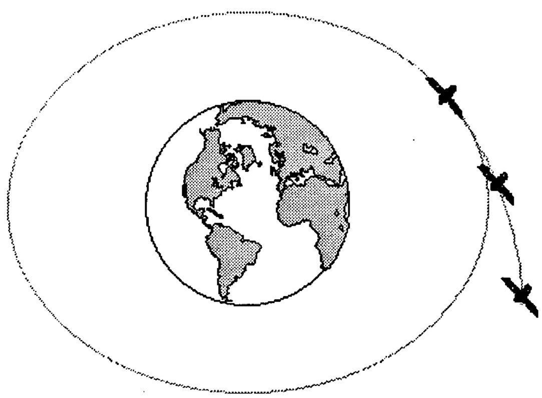
White Papers

- G, Spacelift
- H, Aerospace Replenishment
- W, On-Orbit Support
- Δ, Space Operations

3.2 Orbital Combat Vehicle

Brief Description

The orbital combat vehicle (OCV) is an uninhabited orbital propulsion and docking system used to take payloads from an earth-to-orbit lift vehicle and place them in their final orbital plane or used to fetch and return orbiting payloads to a central repair and recovery location. The system also would be capable of carrying LRUs to a damaged/degraded satellite and accomplishing on-site repair or replacement. It is designed to allow refueling of civil, commercial, and military satellites as well as the rearming of military space weapons platforms. The OCV is fitted with a medium power high-energy laser system for limited defense and counterspace missions.



Capabilities

- Refueling of civil, commercial, and military satellites
- Can maneuver payloads from one earth orbit to another
- Supply/resupply of military space assets
- Limited force application against space assets

Enabling Technologies (MCTL)

- 2.2, Metal Working and Industrial Production
  - 2.2.5, Robots, Controllers, and End Effectors
- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 4.2, Software
  - 4.2.9, Artificial Intelligence
- 9.5, Aerospace Structures and Systems
  - 9.5.2, Nonchemical, High-Specific Impulse Propulsion
- 10.1, Lasers
- 10.3, Power Systems

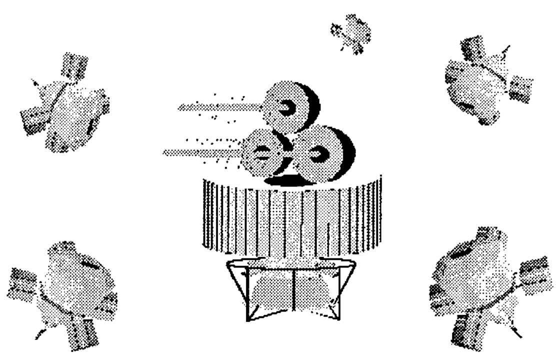
White Papers

- W, On-Orbit Support
- Δ, Space Operations

3.3 Satellite Bodyguards

Brief Description

A small constellation of defensive satellites (e.g., five) placed in proximity to the protected asset. "Hunter killers" actively seek out threats and incapacitate them with directed energy weapons. Detection of threats from the surface or air would be done by an off-board sensor suite (e.g., systems 8.1 or 8.2) and supplied to the "hunter-killer" satellites. Detection of space-based threats would be done by the hunter-killer satellites themselves. Decoy satellites appear identical (both EM and visual) to the protected assets to confuse an aggressor; when approached, the decoy can impact and disable the enemy craft.



Capabilities

- Defensive satellites provide protection for high-valued space-based assets
- Active defense hunter-killer and decoy satellites seek out and destroy approaching threats

Enabling Technologies (MCTL)

- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.3, Signal Processing
- 4.2, Software
  - 4.2.5, Data Fusion
- 9.4, Rockets
- 10.2, Optics
- 10.3, Power Systems
- 11.1, High-Energy Laser Systems

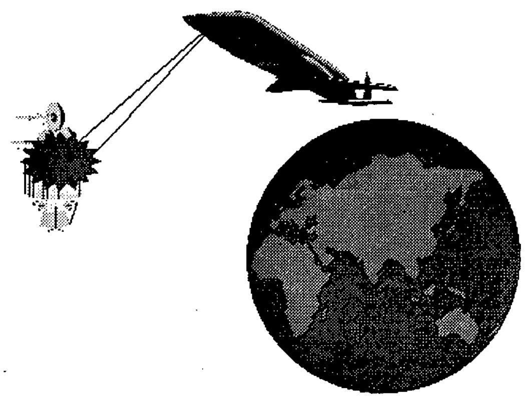
White Papers

- C, Counterspace

4.1 Piloted SSTO Transatmospheric Vehicle

Brief Description

This system provides space support and global reach from the earth's surface to low-earth orbit (LEO) using a combination of rocket and hypersonic air-breathing technology. The transatmospheric vehicle (TAV) envisioned takes off vertically, is refuelable in either air or space, and can land on a conventional runway. It has a variable payload capacity (up to 10,000 lbs) and performs as both a sensor and a weapons platform. Alternate missions include satellite deployment and retrieval from LEO and deployment of an ASAT weapon.



Capabilities

- Single-stage manned TAV capable of providing rapid support to space-based assets from the ground
- Repair or retrieval of satellites in LEO
- Surveillance and reconnaissance platform
- Payload capacity of 10,000 lbs
- ASAT weapons platform

Enabling Technologies (MCTL)

- 1.0, Materials
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 9.2, Ramjet, Scramjet, Combined Cycle Engines
- 9.5, Aerospace Structures and Systems
  - 9.5.4, Aircraft High-Performance Structures
- 12.7, Military Explosives (Energetic Materials)

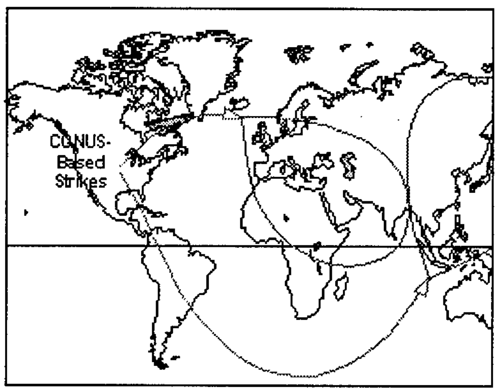
White Papers

- C, Counterspace
- Δ, Space Operations
- F, Airlift
- G, Spacelift
- N, Strategic Attack

4.2 Uninhabited Air-Launched Transatmospheric Vehicle

Brief Description

This uninhabited vehicle is a multirole transatmospheric vehicle (TAV). Launched from an airborne platform (e.g., System 1.1), it is capable of rapid deployment (or retrieval) of satellites providing communication links, and intelligence information. It carries a suite of multispectral sensors (optical, infrared, radar, and laser.) for surveillance and reconnaissance missions. This TAV is a rocket-powered vehicle, approximately the size of an F-15 and is capable of carrying several small satellites (e.g., 6 ft by 6 ft by 6 ft, 1,000 lbs each) to low-earth orbit (LEO). Further, it could perform an antisatellite (ASAT) role. This TAV can land on a conventional runway.



Capabilities

- Rocket-powered "upper-stage" TAV
- Air-launched by hypersonic strike fighter
- Rapid deployment of multiple satellites to LEO
- Repair or retrieval of satellites in LEO
- Surveillance and reconnaissance platform
- Space-based ASAT

Enabling Technologies (MCTL)

- 1.0, Materials
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 4.2, Software
  - 4.2.5, Data Fusion
- 9.4, Rockets
- 9.5, Aerospace Structures and Systems
  - 9.5.3, Aerospace Thermal Systems
  - 9.5.4, Aircraft High-Performance Structures
- 12.7, Military Explosives (Energetic Materials)

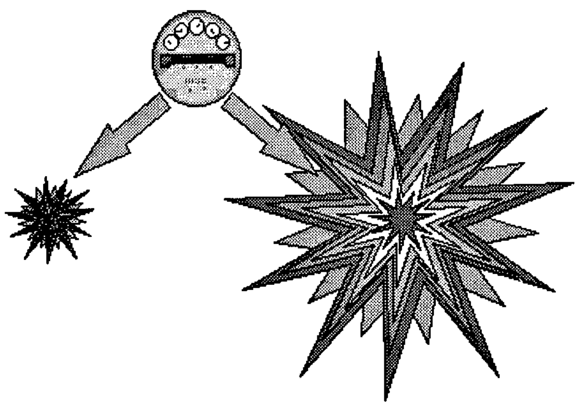
White Papers

- Σ1, AFIT Space Operations
- Ψ, Hypersonics

5.1 Adjustable Yield Munition

Brief Description

The adjustable yield munition (AYM) is an approach to achieve precise matching of the weapon's effect to the target's characteristics. By manipulating the explosive yield of a weapon (i.e., "dial-a-yield"), collateral damage can be greatly reduced. This is particularly advantageous when flexibility and precision are both required: a platform on patrol, awaiting targets of opportunity, can utilize the same weapon for a hard kill with a large yield, or a surgical, mission-only kill with a tailored yield. One proposed approach to controlling the yield is to change the material composition of the explosive at the molecular level.



Capabilities

- Precision tailoring of munitions yield to individual target characteristics
- Provides precision strike capability with minimal collateral damage

Enabling Technologies (MCTL)

- 12.7, Military Explosives (Energetic Materials)

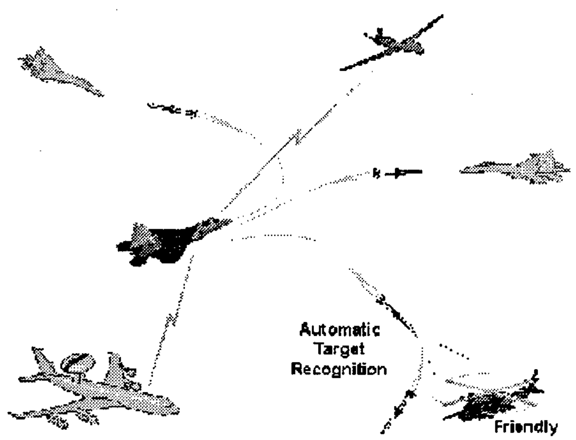
White Papers

- K, Interdiction

5.2 Advanced Air-to-Air Missile

Brief Description

This long-range air-to-air missile receives real-time target information from off-board sensors and utilizes reactive jets and an on-board computer to acquire, pursue, and destroy enemy air assets including cruise missiles. Terminal tracking and guidance may employ a combination of LIDAR, infrared (IR), radio frequency (RF), magnetic anomaly detection (MAD), jet engine modulation (JEM), photographic and acoustic sensors.



Capabilities

- 100+ NM range air-to-air missile that can engage and destroy airborne targets with a high probability of kill (>.9)
- Counters low observable (LO) targets
- Counter countermeasures enable this system to target high-value enemy surveillance and control and jamming airborne platforms

Enabling Technologies (MCTL)

- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 4.2, Software
  - 4.2.5, Data Fusion
- 6.1, Air, Marine, Space Platform and Terrestrial Acoustic Systems
- 6.2, Optical Sensors
- 6.4, Electronic Combat (EC)
- 6.5, Magnetometers and Magnetic Gradiometers
- 6.8, Radar
- 6.9, Other Sensors
- 7.3, Vehicle and Flight Control

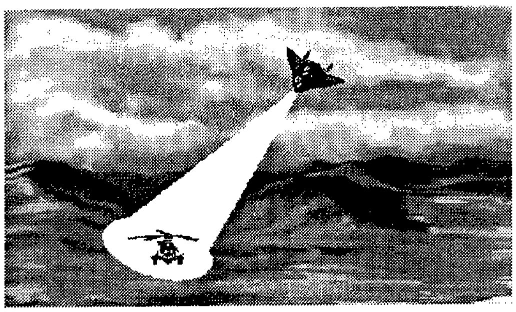
White Papers

- A, Counterair

5.3 Airborne High-Power Microwave Weapon

Brief Description

A pulsed power airborne high-power microwave (HPM) system is proposed. This medium-range weapons system would constitute the primary payload of the host escort defense aircraft. The system generates variable magnitude HPM fields that disrupt or destroy electrical components in the target region. The HPM weapon envisioned is capable of engaging both air and ground targets.



Capabilities

- Aircraft defense against weapon systems and munitions having sensitive electrical components
- The ability to strike against air and surface targets with variable lethality

Enabling Technologies (MCTL)

- 1.0, Materials
- 10.3, Power Systems
- 11.2, High-Power Radio Frequency (RF) Systems

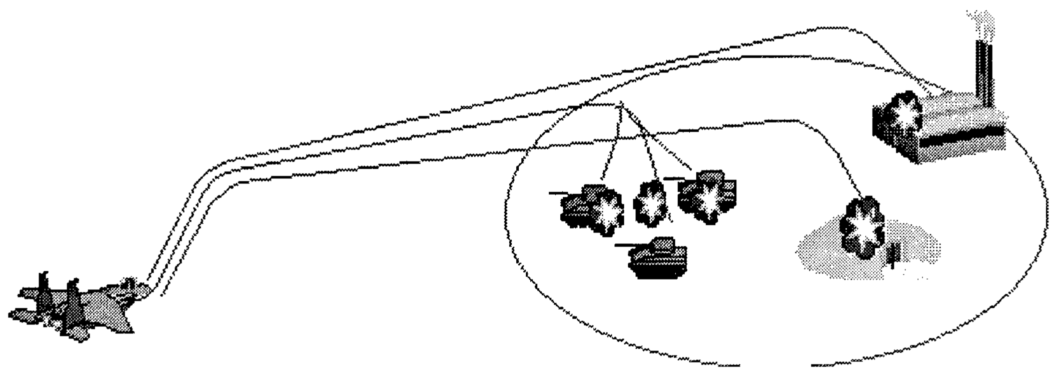
White Papers

- K, Interdiction
- A, Counterair

5.4 Standoff Hypersonic Missile

Brief Description

This hypersonic air-to-ground missile is launched from a hypersonic strike vehicle (System 1.1) and utilizes a Scramjet to propel itself at Mach 8 toward the intended high-value target. It then glides to target at Mach 4 and its flight trajectory altered as needed by way of off-board control. Its high speed air-launched range is 1,450 NM.



Capabilities

- Hypersonic theater-range precision ground strike munition
- Launched at Mach 8, its range is 1450 NM
- Terminally guided to the target by way of off-board control

Enabling Technologies (MCTL)

- 1.2, Composite Materials
- 5.1, Transmission
- 9.2, Ramjet, Scramjet, and Combined Cycle Engines
- 9.5.4, Aircraft High-Performance Structures
- 12.7, Energetic Materials

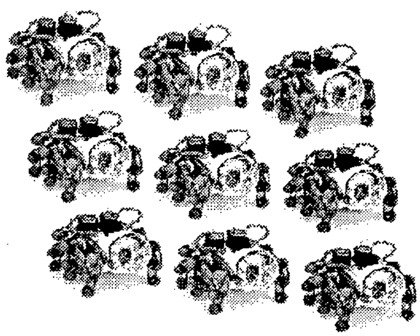
White Papers

- Ψ, Hypersonics

5.5 Attack Microbots

Brief Description

"Attack microbots" describes a class of highly miniaturized (one millimeter scale) electromechanical systems capable of being deployed en masse and performing individual or collective target attack. Various deployment approaches are possible, including dispersal as an aerosol, transportation by a larger platform, and full flying/crawling autonomy. Attack is accomplished by a variety of robotic effectors, electromagnetic measures, or energetic materials. Some "sensor microbot" capabilities are required for target acquisition and analysis.



Capabilities

- "Swarm" of 1 mm scale flight-capable MEM platforms provide unobtrusive, pervasive intervention into adversary environments and systems
- Extremely small size provides high-penetration capabilities and natural stealth

Enabling Technologies (MCTL)

- 2.2.5, Robots, Controllers and End-Effectors
- 2.6, Micromechnical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 4.2, Software
  - 4.2.5, Data Fusion
- 5.1, Transmission
- 5.4, C^4I
- 7.3, Vehicle and Flight Control
- 10.3, Power Systems
- 12.7, Energetic Materials

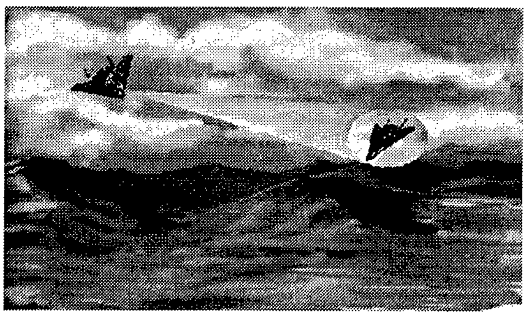
White Papers

- A, Counterair
- C, Counterspace
- Q, Special and Humanitarian Operations

5.6 Airborne Holographic Projector

Brief Description

The holographic projector displays a three-dimensional visual image in a desired location, removed from the display generator. The projector can be used for psychological operations and strategic perception management. It is also useful for optical deception and cloaking, providing a momentary distraction when engaging an unsophisticated adversary.



Capabilities

- Precision projection of 3-D visual images into a selected area
- Supports PSYOP and strategic deception management
- Provides deception and cloaking against optical sensors

Enabling Technologies (MCTL)

- 4.1.4, Image Processing (holographic displays)
- 10.1, Lasers
- 10.2, Optics
- 10.3, Power Systems

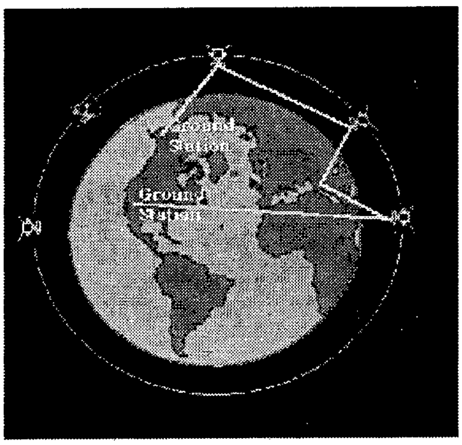
White Papers

- Q, Special and Humanitarian Operations
- N, Strategic Attack

5.7 Hybrid High-Energy Laser System

Brief Description

The hybrid high-energy laser system (HHELS) consists of several ground-based, multi-megawatt high-energy chemical lasers and a constellation of space-based mirrors. The HHELS can be used in several modes of operation. In its weapons mode with the laser at high power, it engages air, space, and ground targets by reflecting a laser beam off one or more of the mirrors to the intended target. It also can be used for target tracking, limited space debris removal (1–10 centimeter objects), and replenishment of satellites.



Capabilities

- Worldwide coverage provided by several ground laser sites and a constellation of 15–20 space-based mirrors
- Has counterspace, counterair, force application, and weather modification uses
- Replenishes some space-based assets
- Ground laser sites have a limited space surveillance capability

Enabling Technologies (MCTL)

- 9.5, Aerospace Structures and Systems
  - 9.5.1, Spacecraft Structures
  - 9.5.2, Nonchemical, High-Specific Impulse Propulsion
- 10.2, Optics
- 10.3, Power Systems
- 11.1, High-Energy Laser Systems

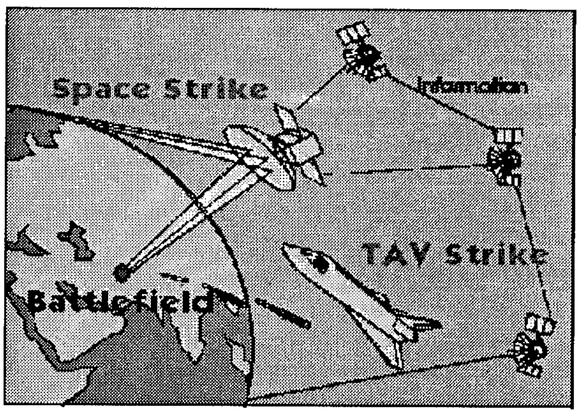
White Papers

- Δ, Space Operations

6.1 Global Area Strike System

Brief Description

The global area strike system (GLASS) consists of a high-energy laser (HEL) system, a kinetic energy weapon (KEW) system and a transatmospheric vehicle (TAV). The HEL system consists of ground-based lasers and space-based mirrors which direct energy to the intended target. The KEW system (System 6.2) consists of terminally guided projectiles, with and without explosive enhancers. The TAV (System 4.1) is a flexible platform capable of supporting maintenance and replenishment of the HEL and KEW space assets and also could be used for rapid deployment of special operations forces. Target definition and sequencing is managed externally (i.e., using GIMS [System 8.1]).



Capabilities

- Uses a constellation of space-based KEWs and hybrid (ground-based) high-energy lasers to provide precision global engagement of ground, space and airborne targets, with variable lethality
- Provides extensive surveillance capability using TAVs and ground-based laser sites
- Rapid deployment from ground to LEO using TAV fleet
- Limited weather modification uses

Enabling Technologies (MCTL)

- 1.0, Materials
- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 5.1, Transmission
- 7.3, Vehicle and Flight Control
- 9.2, Ramjet, Scramjet, Combined Cycle Engines
- 9.5, Aerospace Structures & Systems
  - 9.5.1, Spacecraft Structures
  - 9.5.4, Aircraft High-Performance Structures
- 10.2, Optics
- 11.1, High-Energy Laser Systems
- 11.4, Kinetic Energy Systems
  - 11.4.2, Kinetic Energy Projectiles
  - 11.4.4, Kinetic Energy Platform Management
- 12.7, Energetic Materials

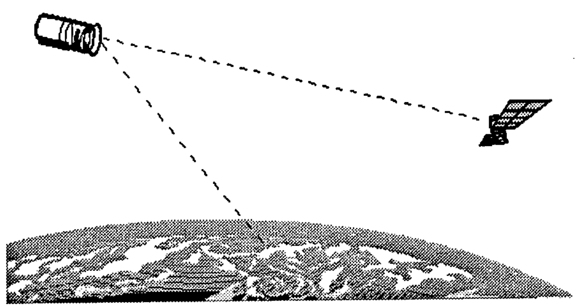
White Papers

- Δ, Space Operations

6.2 Space-Based Kinetic Energy Weapon

Brief Description

The space-based KEW is a general class of LEO based weapons that include a variety of warhead types from flechettes and pellets to large and small high-density rods. The KEW may be directed at air, space, and ground targets and achieves its destructive effect by penetrating the target at hypervelocity. Sensor information is provided to the KEW by a main sensor suite off-board of the vehicle (such as GSRT [System 8.2] or GIMS [System 8.1]). However, each armament has a minimal sensor capability (i.e., GPS receiver) and a simple flight control system for maneuver.



Capabilities

- Precision global engagement of space, air, and ground targets using a constellation of space-based KEW platforms
- Micro and larger space-delivered kinetic energy munitions
- Provide concentrated or dispersed target coverage

Enabling Technologies (MCTL)

- 1.0, Materials
- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 5.1, Transmission (Communications)
- 7.3, Vehicle and Flight Control
- 11.4, Kinetic Energy Systems
  - 11.4.2, Kinetic Energy Projectiles
  - 11.4.4, Kinetic Energy Platform Management

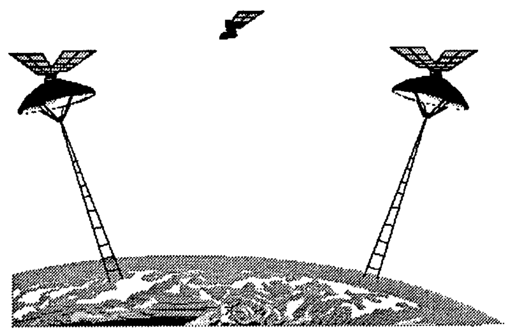
White Papers

- C, Counterspace
- N, Strategic Attack
- Δ, Space Operations

6.3 Space-Based High-Power Microwave Weapon

Brief Description

The space-based high-power microwave (HPM) weapon system is capable of engaging ground, air, and space targets with a varying degree of lethality. It consists of a constellation of satellites deployed in LEO (approx. 500 NM) that can direct an ultra wide-band (UWB) of microwave energy at ground, air, and space targets. Its effect is to generate high-electric fields over a target area tens to hundreds of meters in size, thereby disrupting or destroying any electronic components present.



Capabilities

- Engage ground, space and airborne targets containing sensitive electrical components
- Variable lethality, from disrupt to destroy
- Provides limited weather modification capability

Enabling Technologies (MCTL)

- 1.0, Materials
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 9.5, Aerospace Structures and Systems
  - 9.5.1, Spacecraft Structures
- 10.3, Power Systems
- 11.2, High-Power Radio Frequency Systems

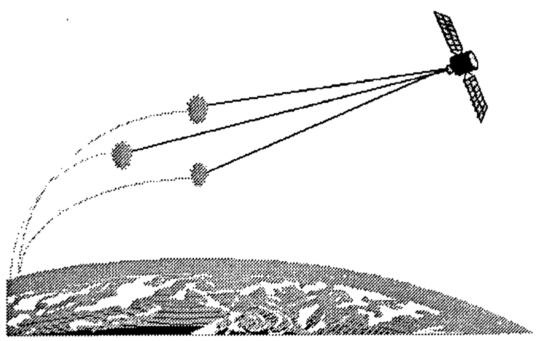
White Papers

- A, Counterair
- C, Counterspace
- Q, Special and Humanitarian Operations
- Γ, Weather Modification
- Δ, Space Operations

6.4 Space-Based High-Energy Laser System

Brief Description

The space-based high energy laser system is a space-based, multimegawatt, high-energy chemical laser constellation that can be used in several modes of operation. In its weapons mode with the laser at high power, it can attack ground, air, and space targets. In its surveillance mode, it can operate using the laser at low-power levels for active illumination imaging or with the laser inoperative for passive imaging.



Capabilities

- Worldwide coverage provided by constellation of 15–20 chemical HELs
- Provides optical surveillance of air, space, and ground objects using active or passive imaging
- Provides precision strike of air, space, and ground targets with variable lethality
- Provides limited weather modification capability

Enabling Technologies (MCTL)

- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.3, Signal Processing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.4, Hard Real-Time Systems
  - 4.2.5, Data Fusion
- 10.2, Optics
- 10.3, Power Systems
- 11.1, High-Energy Laser Systems

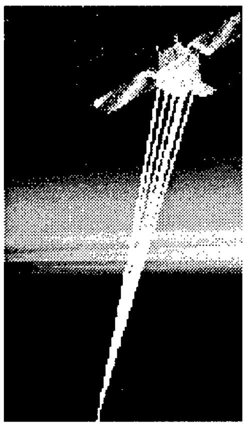
White Papers

- A, Counterair
- C, Counterspace

6.5 Solar-Powered High-Energy Laser System

Brief Description

The solar-powered high-energy laser system is a space-based, multimegawatt, high energy solar-powered laser constellation that can be used in several modes of operation. In its weapons mode with the laser at high power, it can attack ground, air, and space targets. In its surveillance mode, it can operate using the laser at low-power levels for active illumination imaging, or with the laser inoperative for passive imaging.



Capabilities

- Variable lethality, space-based solar-powered high-energy laser constellation
- Provides global optical surveillance by active or passive imaging
- Engages ground, space, and airborne targets
- Possible application in weather modification

Enabling Technologies (MCTL)

- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.3, Signal Processing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.4, Hard Real-Time Systems
  - 4.2.5, Data Fusion
- 10.2, Optics
- 10.3, Power Systems
- 11.1, High-Energy Laser Systems

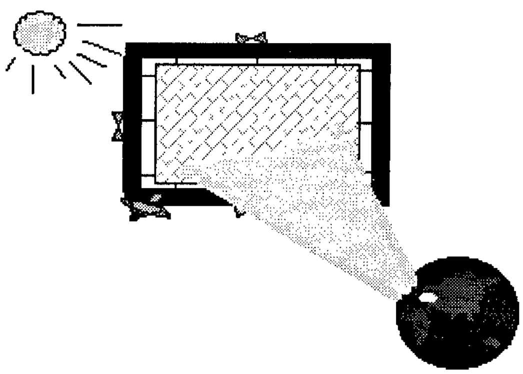
White Papers

- C, Counterspace
- Δ, Space Operations

6.6 Solar Energy Optical Weapon

Brief Description

The solar energy optical weapon (SEOW) consists of a constellation of space-based mirrors which allow solar radiation to be focused on specific ground, air, or space targets. The lethality of this system is limited, due to optical diffusion; however, it may prove useful for disruption or perhaps weather control.



Capabilities

- Space-based solar "flashlight"
- Illuminates air, ground, and space targets with focused solar radiation
- Engage space-based targets with variable lethality (heating caused by focused solar radiation)
- Focuses solar energy on ground-based collectors
- Could potentially be used for weather modification

Enabling Technologies (MCTL)

- 2.2, Metal Working and Industrial Production
  - 2.2.5, Robots, Controllers, and End Effectors
- 9.5, Aerospace Structures and Systems
  - 9.5.1, Spacecraft Structures
- 10.2, Optics
- 10.3, Power Systems

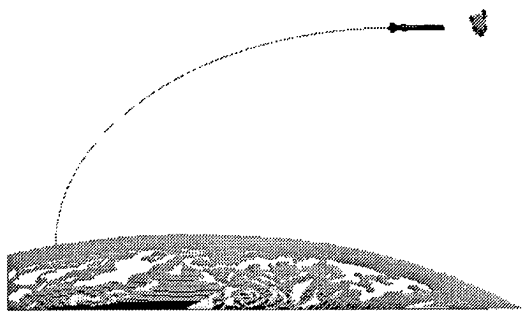
White Papers

- C, Counterspace
- Δ, Space Operations

6.7 Asteroid Mitigation System

Brief Description

The asteroid mitigation system protects the Earth/Moon system from earth-crossing objects (ECO) by either deflecting or fragmenting ECO they no longer pose a threat. Deflection could be accomplished using nuclear explosive devices.



Capabilities

- Deflects or destroys objects in space having the size and trajectory to threaten the Earth/Moon system

Enabling Technologies (MCTL)

- 7.3, Vehicle and Flight Control
- 9.5, Aerospace Structures and Systems
  - 9.5.2, Nonchemical, High "Specific Impulse" Propulsion
- 12.7, Military Explosives (Energetic Materials)

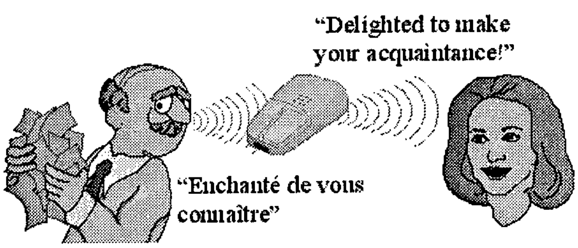
White Papers

- B, Planetary Defense

7.1 Spoken Language Translator

Brief Description

This hand-held or worn device translates oral communications in near real time. It would enhance multinational operational effectiveness in all areas, including training, diplomacy, special operations, and conventional ground operations. It is capable of one-for-one word substitution in a wide variety of languages and provides two-way communications between the owner and another person. The system will have a limited ability to compensate for differences in sentence syntactic structures, cultures, dialects, and idioms/slang and a limited ability to select words according to context. Careful placement of both microphones and both speakers is required for deconfliction (not having to hear both languages simultaneously), limiting the scope of its operation; the system is best suited for such controlled two-way communications as telephone, radio, or computer. The system also would be useful for written text translation.



Capabilities

- Near real time speech translation
- Bidirectional, multilingual

Enabling Technologies (MCTL)

- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.6, Speech-Processing Systems
- 4.2, Software
  - 4.2.9, Artificial Intelligence

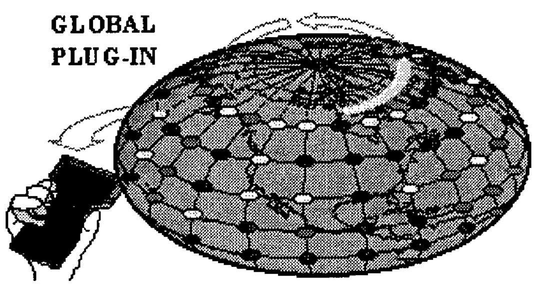
White Papers

- Q, Special and Humanitarian Operations

7.2 Personal Digital Assistant

Brief Description

The personal digital assistant (PDA) connects an individual to the information systems of 2025. PDA is envisioned as a hand held or wrist-watch size unit. Possible input modes include both touch and voice. It is the warrior's secure, high-capacity connection to the distributed C^4I system. The PDA maintains the owner's personal data such as medical and training records. It learns and remembers the owner's preferences and needs so that requests for information are properly tailored. It is self-securing: it recognizes the owner through a number of biometrics and ensures that it cannot be commandeered. In short, the PDA is a single device that can replace the cellular telephone, radio, personal computer, identification and banking cards, and any other personal information-management device of today.



Enabling Technologies (MCTL)

- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
- 4.1.1, High-Performance Computing
- 4.1.3, Signal Processing
- 4.1.6, Speech Processing
- 4.2, Software
  - 4.2.9, Artificial Intelligence
- 5.1, Transmission
- 5.3, Communications Network Management and Control
- 5.5, Information Security
- 10.3, Power Systems

White Papers

- J, Close Air Support
- K, Interdiction
- M, Information Operations
- Q, Special and Humanitarian Operations
- R, Special Operations
- T, Space S&R Fusion
- U, S&R Information Operations
- V, S&R Real Time Integration
- Z, Information Technology Integration in Education and Training
- Θ, Combat Support

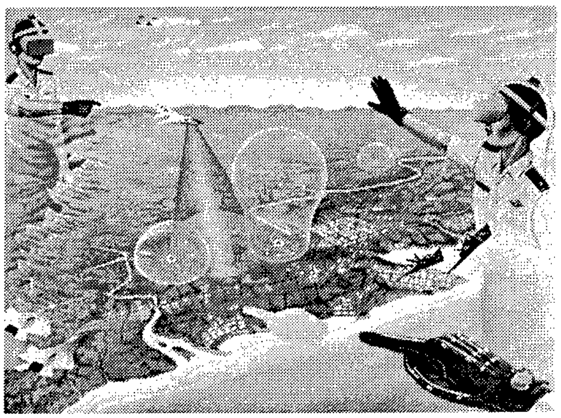
Capabilities

- Warriors can attain situational awareness, act as a sensor (reconnaissance) node, and receive instructions/commands
- Commanders can monitor the status of their troops by way of the physiological measures relayed by the PDA
- It also contains an identification friend or foe (IFF) module

7.3 Virtual Interaction Center

Brief Description

The Virtual Interaction Center describes a virtual reality environment in which commanders can immerse themselves in a three-dimensional representation of the battlespace. Information from a global information system, including GIMS (System 8.1), is displayed in a virtual reality environment, giving the commander situational awareness. The center also has the capability to replay battles and engagements and to simulate "what if" scenarios.



Capabilities

- Immersive virtual reality environment to view and control battlespace
- Provides commanders with situational awareness and C^4 functions in a collaborative environment
- Simulation capability for "what if" exercises
- Simulation and virtual reality environment for education and training

Enabling Technologies (MCTL)

- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.2, Dynamic Training and Simulation
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.4, Hard Real-Time Systems

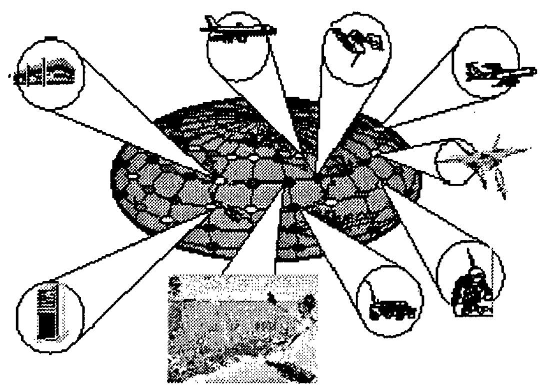
White Papers

- A, Counterair
- J, Close Air Support
- K, Interdiction
- M, Information Operations
- N, Strategic Attack
- Q, Special and Humanitarian Ops
- U, S&R Information Operations
- V, S&R Real-Time Integration
- W, On-Orbit Support
- X, General Education & Training
- Z, Information Technology Integration in Education & Training
- Θ, Combat Support
- Σ2, AFIT Space Operations

8.1 Global Information Management System

Brief Description

The global information management system is a pervasive network of intelligent information-gathering, processing, analysis, and advisory nodes. It collects, stores, analyzes, fuses, and manages information from ground/air/space sensors and all source intelligence. All types of sensors (i.e., acoustic, optical, radio frequency, and olfactory) are used. However, the true power of this system is its use of neural processing to provide the right type of information based on the user's personal requirements.



Capabilities

- Provides situational and battle-space awareness, tailored to each user's needs and interests
- Provides extensive information warfare capability
- Uses neural networks, artificial intelligence, and intelligent software agents to gather, synthesize, and format information
- Provides human interfaces through Personal Digital Assistants, Virtual Interaction Centers, and other systems

Enabling Technologies (MCTL)

- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.2, Dynamic, Training, and Simulation
  - 4.1.3, Signal Processing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.4, Hard Real-Time Systems
  - 4.2.5, Data Fusion
  - 4.2.9, Artificial Intelligence
- 5.1, Transmission
- 5.3, Communications Network Management and Control
- 5.4, Command, Control, Communications, and Intelligence Systems
- 5.5, Information Security
- 5.3, Communications Network Management and Control
- 6.1, Air, Marine, Space Platform, and Terrestrial Acoustic Systems
- 6.2, Optical Sensors
- 6.6, Magnetometers and Magnetic Gradiometers
- 6.7, Gravity Meters and Gravity Gradiometers
- 6.8, Radar
- 6.9, Other Sensors

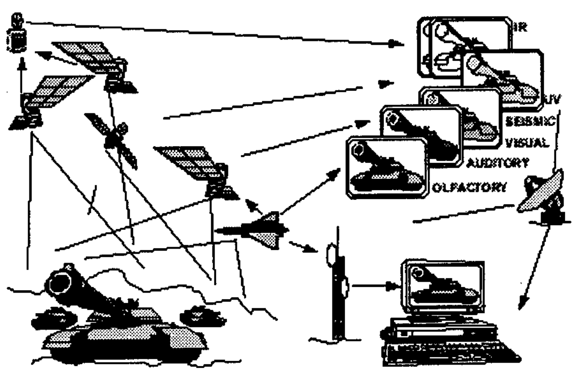
White Papers

- A, Counterair
- B, Planetary Defense
- C, Counterspace
- J, Close Air Support
- K, Interdiction
- M, Information Operations
- N, Strategic Attack
- T, Space S&R Fusion
- U, S&R Information Operations
- V, S&R Real-Time Integration
- W, On-Orbit Support
- Θ, Combat Support
- Σ2, AFIT Space Operations
- Φ, Logistics

8.2 Global Surveillance, Reconnaissance, and Targeting System

Brief Description

The global surveillance, reconnaissance, and targeting system (GSRT) is a space-based omnisensorial collection, processing, and dissemination system to provide a real-time information database. This database is used to create a virtual reality image of the area of interest. This image can be used at all levels of command to provide situational awareness, technical and intelligence information, and two-way command and control.



Capabilities

- Real-time information on demand to war fighter
- Smaller, distributed, proliferated satellites and space-based sensors
- Omnisensorial collection, processing and information dissemination
- Space-based fusion and data storage

Enabling Technologies (MCTL)

- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.3, Signal Processing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.4, Hard Real-Time Systems
  - 4.2.5, Data Fusion
- 5.1, Transmission
- 5.3, Communications Network Management and Control
- 5.4, Command, Control, Communications, and Intelligence Systems
- 5.5, Information Security
- 6.1, Air, Marine, Space Platform, and Terrestrial Acoustic Systems
- 6.2, Optical Sensors
- 6.6, Gravity Meters and Gravity Gradiometers
- 6.7, Radar

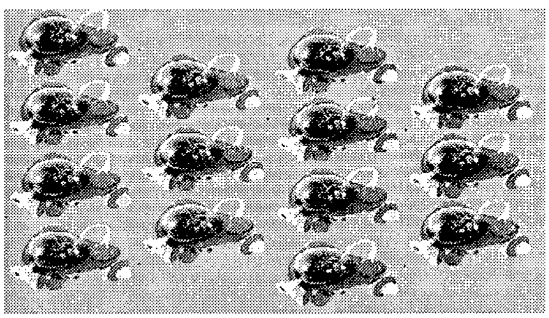
White Papers

- W, On-Orbit Support

8.3 Sensor Microbots

Brief Description

Sensor microbots describes a class of highly miniaturized (millimeter-sized) electromechanical air and ground systems capable of being deployed en masse to collect data, perform individual and collective data fusion, and communicate that data for further processing and distribution. Various deployment approaches are possible, including dispersal as an aerosol, transportation by a larger platform, and full-flying/crawling autonomy. Data collection is accomplished through miniaturized onboard sensors, typically restricted to one or two sensors per unit due to size and power limitations. Communications are possible by transmission through relay stations "relaybots" or physical collection of the microbots. Some applications of sensor microbots are security net to guard own assets, surveillance and reconnaissance, and intelligence gathering on adversary assets.



Capabilities

- "Swarm" of one millimeter scale, flight-capable MEM platforms provide unobtrusive, pervasive, multispectral sensing
- Small size provides high-penetration capabilities and natural stealth

Enabling Technologies (MCTL)

- 2.2, Metal Working and Industrial Production
  - 2.2.5, Robots, Controllers and End Effectors
- 2.6, Micromechanical devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.3, Signal Processing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.5, Data Fusion
  - 4.2.9, Artificial Intelligence
- 5.1, Transmission
- 5.4, Command, Control, Communications, and Intelligence Systems
- 6.1, Acoustic Sensors
- 6.2, Optical Sensors
- 6.4, Electronic Combat
- 6.8, Radar
- 6.9, Other Sensors
- 7.3, Vehicle and Flight Control
- 9.5, Aerospace Structures and Systems
- 10.3, Power Systems

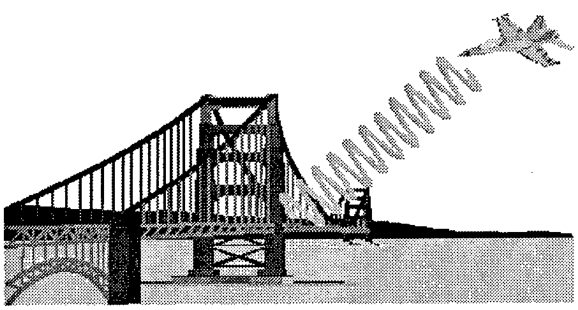
White Papers

- A, Counterair
- D, Operability and Defense
- J, Close Air Support
- K, Interdiction
- M, Information Operations
- N, Strategic Attack
- Q, Special and Humanitarian Operations
- T, Space S&R Fusion
- U, S&R Information Operations
- V, S&R Real-Time Integration
- Θ, Combat Support

8.4 Multiband Laser Sensor System

Brief Description

Different frequencies of electromagnetic energy vary in their ability to penetrate materials. For a particular material, one frequency will reflect off the surface, another will penetrate. By employing a suite of laser devices over a wide frequency range, complete internal and external inspection of a structure can be accomplished and a full three-dimensional model can be developed. This tool can be used for nondestructive inspection of components, target vulnerability analysis, target identification and decoy rejection, and reconnaissance. As envisioned, this suite of laser devices would be carried on an airborne platform, but it clearly has ground-based applications also.



Capabilities

- Airborne variable-frequency laser pod provides internal examination of materials and structures
- Precision target vulnerability analysis
- Target identification and decoy rejection
- Structural mapping for reconnaissance
- Nondestructive testing of parts for "right-timed" preventative maintenance

Enabling Technologies (MCTL)

- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.4, Image Processing
- 10.1, Lasers
- 10.2, Optics
- 10.3, Power Systems

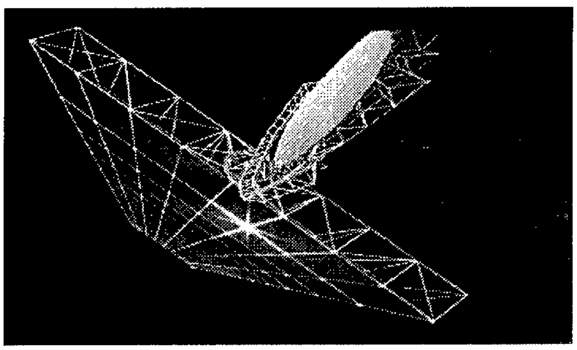
White Papers

- K, Interdiction

8.5 Asteroid Detection System

Brief Description

The asteroid detection system is a network of ground and space sensors which search for, track, and characterize space objects which are large enough and in an orbit to threaten the Earth-Moon system. The system also includes a centralized processing center which fuses data from all of the available sensors, catalogs the known objects, and distributes information to the known authorities.



Capabilities

- Deep-space surveillance—the ability to locate 100-meter-diameter objects at a minimum of one astronomical unit from earth using radar, optical/infrared sensor platforms
- Track and maintain historical data on asteroids and comets
- Provide near real-time feedback on the effects of asteroid mitigation systems (similar to real time BDA)

Enabling Technologies (MCTL)

- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.5, Data Fusion
- 9.5, Aerospace Structures & Systems
  - 9.5.1, Spacecraft Structures

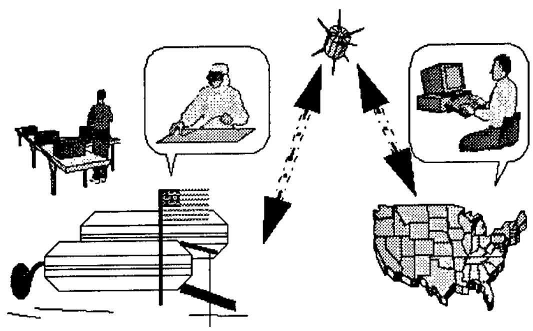
White Papers

- B, Planetary Defense

9.1 Mobile Asset Repair Station

Brief Description

In wartime, replacement parts will be repaired or manufactured in the theater of operations for a variety of deployed weapon systems through the mobile asset repair station (MARS). MARS is a concept whereby parts can be repaired or manufactured using a mobile facility which can be land-based or water-based in the theater of operations, but out of harm's way. The facility features a set of fully integrated flexible manufacturing systems (FMS) and robotic systems that are linked to the commercial manufacturers. These manufacturers supply the specifications to the FMS which then produces the part or component. Many of the required materials necessary for MARS to manufacture the components will be obtained from local countries.



Capabilities

- Manufacture avionics and mechanical system components in-theater
- Uses flexible manufacturing and robotic systems electronically linked to commercial manufacturers
- Cut, repair, and manufacture turn-around times significantly by eliminating need to transport failed (or replacement) parts back to (or from) depot or commercial supplier

Enabling Technologies (MCTL)

- 1.0, Materials
- 2.1, Automation of Industrial Processes, Systems, and Factories
  - 2.1.1, Computer-Aided Design/ Engineering and Interface with Computer-Aided Manufacturing
  - 2.1.2, Computer-Aided Manufacturing, Inspection, and Testing
  - 2.1.3, Computer-Aided Servicing and Maintenance
- 2.2, Metal Working and Industrial Production
  - 2.2.1, Numerically Controlled Machine Tools
  - 2.2.5, Robots, Controllers, and End Effectors
- 2.6, Micromechanical Devices (MEMS)

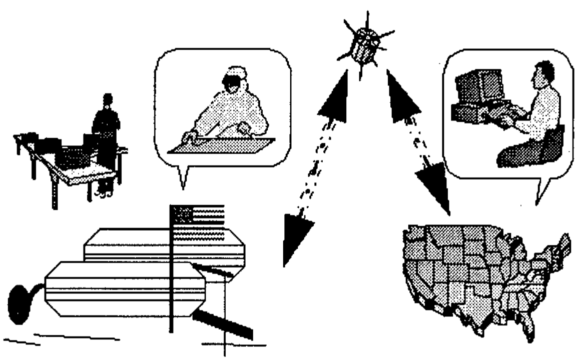
White Papers

- Ω, AFIT Logistics

9.2 Weather Analysis and Modification System

Brief Description

A global network of sensors provides "weather warriors" with the means to monitor and accurately predict weather activities and their effects on military operations. A diverse set of weather modification tools allows manipulation of small-to-medium scale weather phenomena to enhance friendly force capabilities and degrade those of the adversary. Many of the sensors required for this system are assumed to be external (i.e., part of the global information management system [GIMS], discussed in System 8.1).



Enabling Technologies (MCTL)

- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
- 4.2, Software
  - 4.2.5, Data Fusion
  - 4.2.9, Artificial Intelligence
- 4.3, Hybrid Computing
- 6.9, Other Sensors
- 11.2, High-Power RF Systems

White Papers

- Γ, Weather Modification

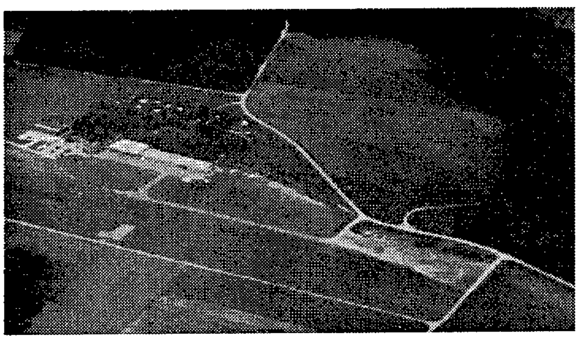
Capabilities

- Understanding and predicting local weather effects on military operations
- Precipitation inducement or suppression using particulate seeding or directed energy
- Fog generation/dissipation using directed energy techniques
- Storm triggering/enhancement using airborne cloud seeding
- High-power microwave (HPM) devices (ground-based) and ionospheric mirrors for communications and radar enhancement/disruption
- Ionospheric charging for spacecraft disruption using crossed HPM beams

9.3 Sanctuary Base

Brief Description

The Sanctuary Base provides a secure, low observable, all-weather forward operating base that reduces the number of assets requiring protection from attack. The runway, power systems, ordnance storage, aircraft maintenance assets, and C^4I systems are self-maintaining and self-repairing. Base security is highly automated. Chemical/biological hazards are cleaned up by nanobots and biotechnology. Robots perform refueling, weapons-loading, maintenance, security, and explosive ordnance destruction.



Capabilities

- Self-defending, self-repairing, and secure
- Facilities, taxiways, and runways are self-diagnostic and self-healing
- Sensors and weapons suite provide complete security within a 50 NM radius
- Orbiting UAVs, robots, and force projectors (DEW/kinetic) provide active defense
- Robots perform refueling, weapons loading, maintenance, EOD, and decontamination
- Low-observable buildings and facilities
- Contains command center using the Virtual Interaction Center

Enabling Technologies (MCTL)

- 1.0, Materials
- 2.1, Automation of Industrial Processes, Systems, and Factories
- 2.2, Metal Working and Industrial Processes, Systems, and Factories
  - 2.2.5, Robots, Controllers, and End Effectors
- 2.6, Micromechanical Devices (MEMS)
- 4.1, Digital Processing
  - 4.1.1, High-Performance Computing
  - 4.1.2, Dynamic Training and Simulation
  - 4.1.4, Image Processing
- 4.2, Software
  - 4.2.4, Hard Real-Time Systems
  - 4.2.9, Artificial Intelligence
- 10.1, Lasers
- 10.3, Power Systems
- 11.1, High-Energy Laser (HEL) Systems
- 11.2, High-Power Radio Frequency (RF) Systems
- 11.4, Kinetic Energy (KE) Systems
  - 11.4.4, Kinetic Energy Platform Management
- 13.3, Chemical/Biological Warfare Defensive Systems

White Papers

- D, Operability and Defense

Appendix C

Alternate Futures Weights

This appendix presents the value model weights for each of the six alternate futures. There are two sets of weights for each future. One set is the average of the weights given by the student members of the ***2025*** writing teams and is denoted "AU Team Weights" (fig. C-1 through fig. C-6). The other set was developed by the ***2025*** Alternate Futures team and is denoted "Alt Futures Team Weights" (fig. C-7 through fig. C-12). The final three figures (fig. C-13 through fig. C-15) contain the weights for the value model force qualities. These were the same for both weight sets across all alternate futures.

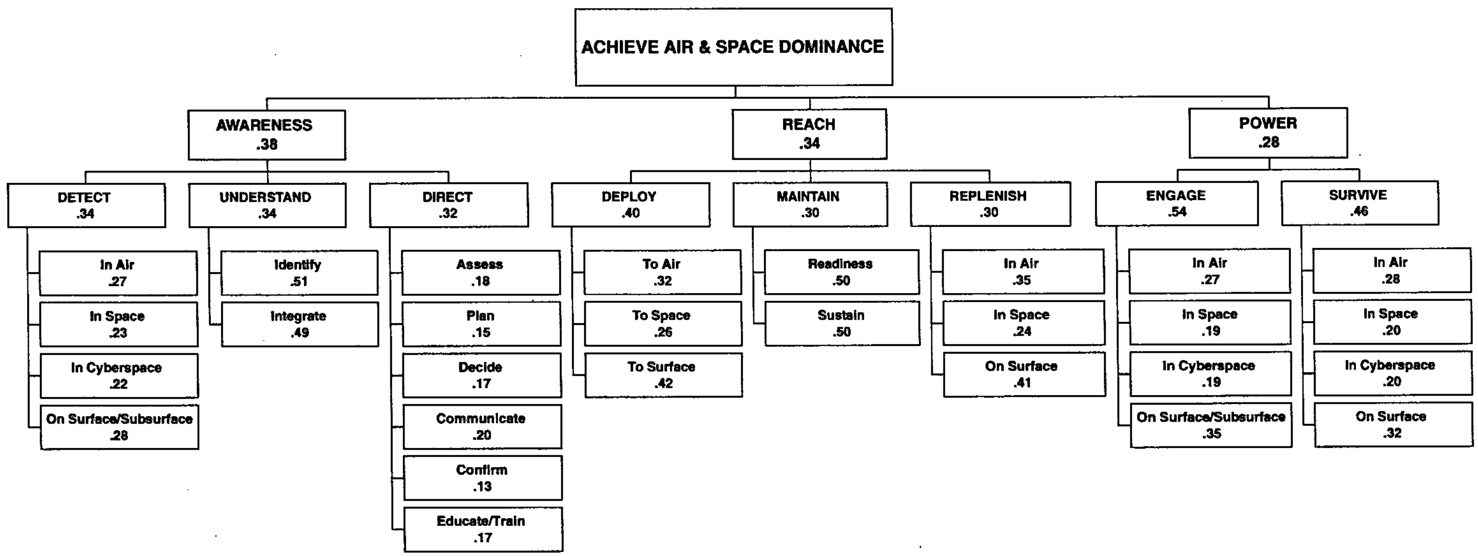


Figure C-1. AU Team Weights—Halfs Future

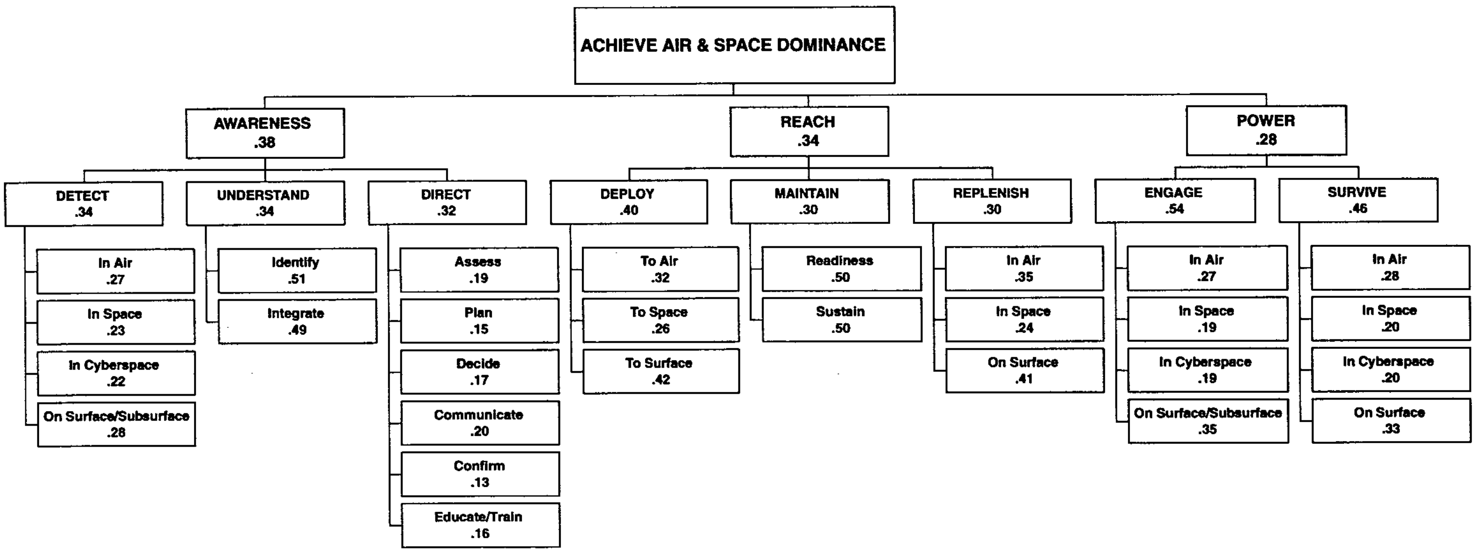


Figure C-2. AU Team Weights—Gulliver's Future

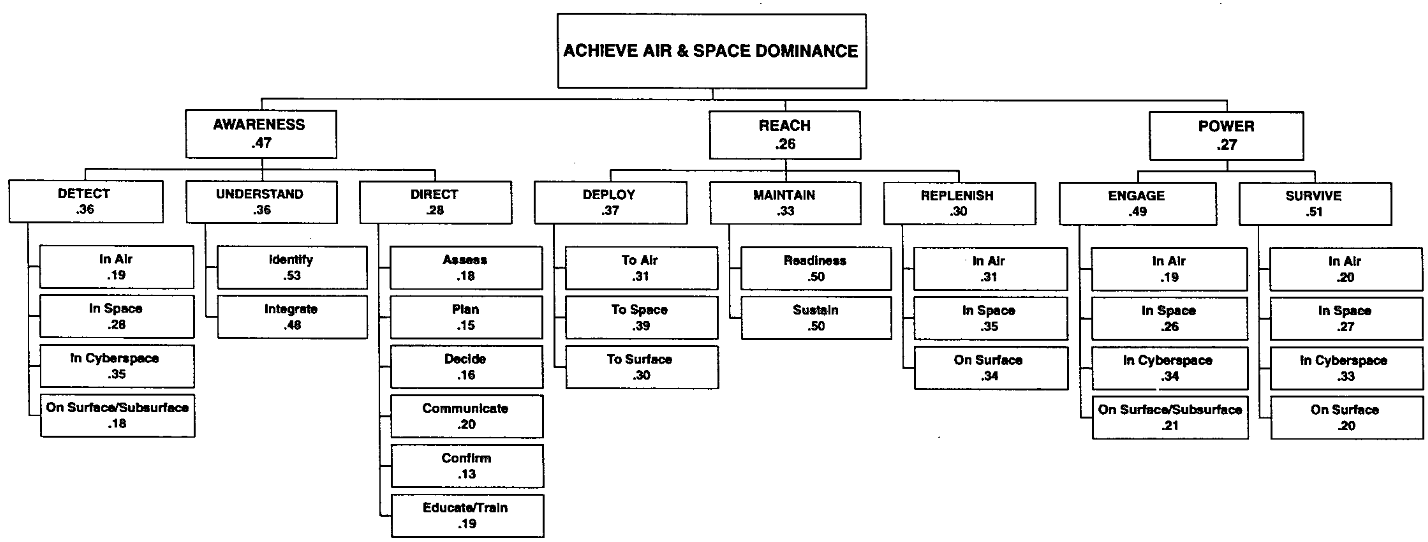


Figure C-3. AU Team Weights—Zaibatsu Future

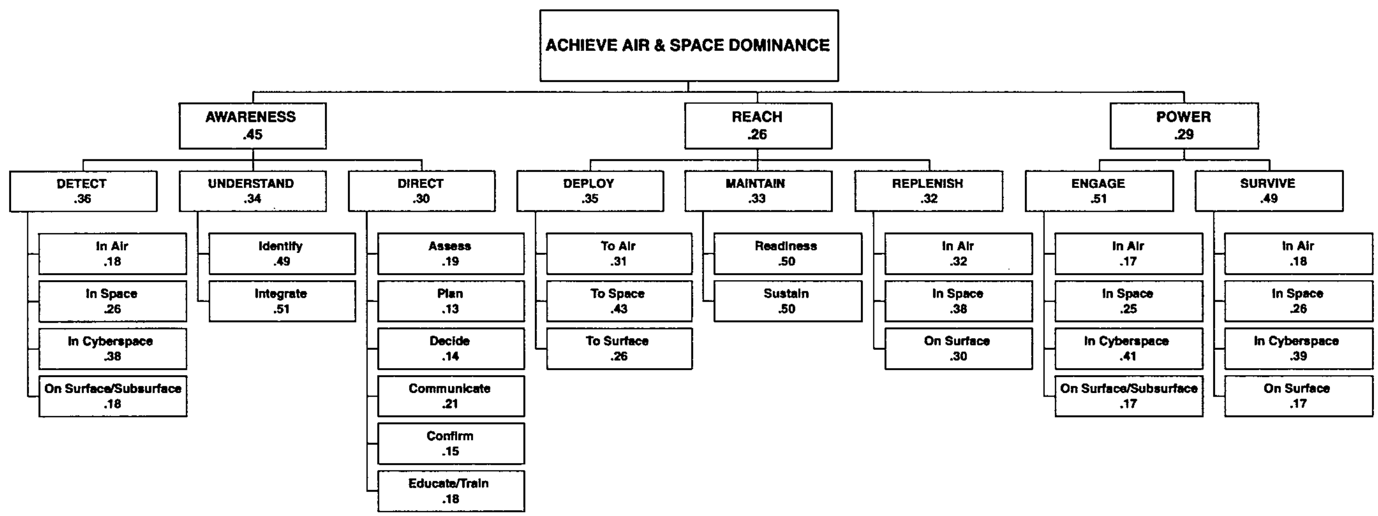


Figure C-4. AU Team Weights—Digital Future

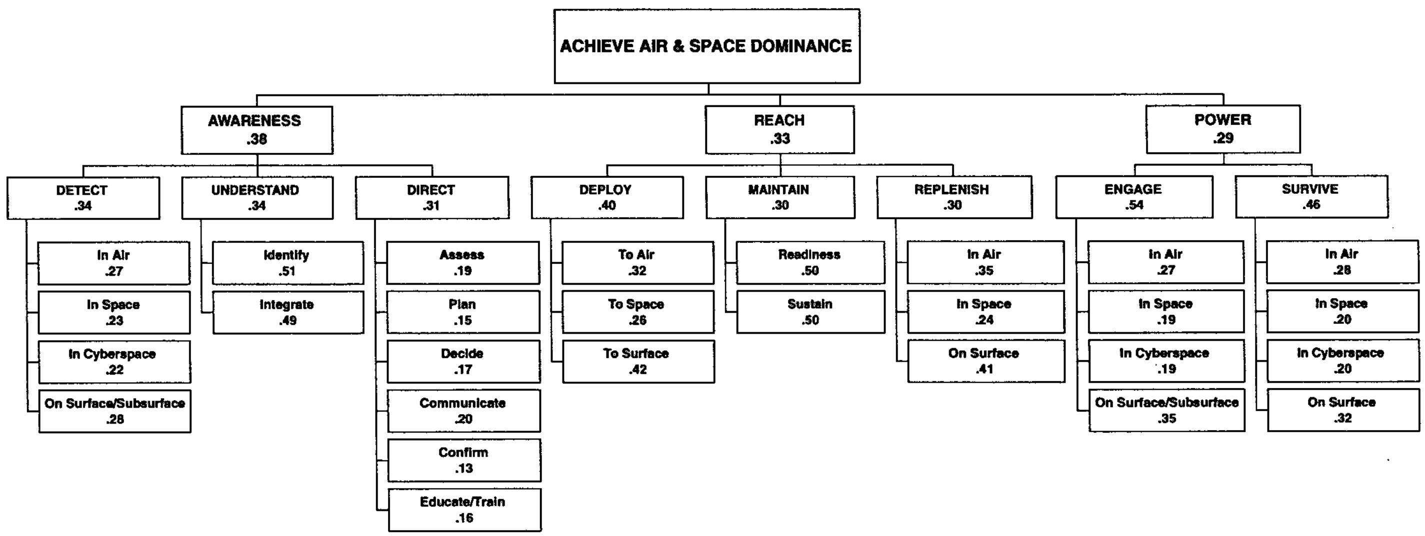


Figure C-5. AU Team Weights—Khan Future

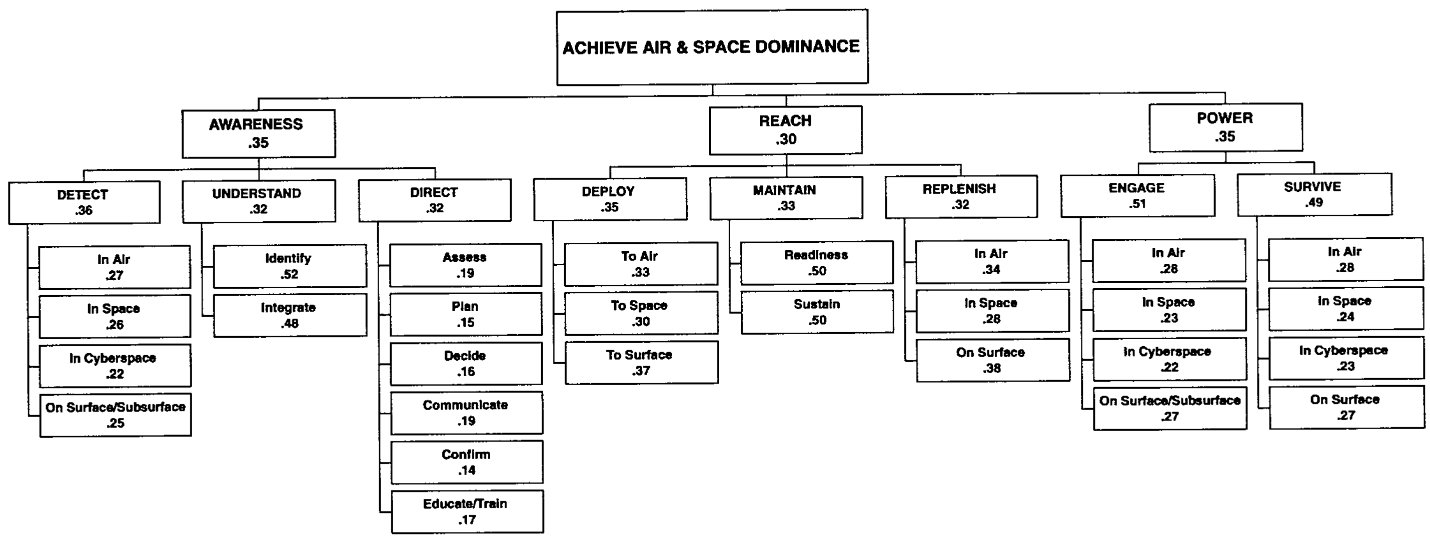


Figure C-6. AU Team Weights—2015 Future

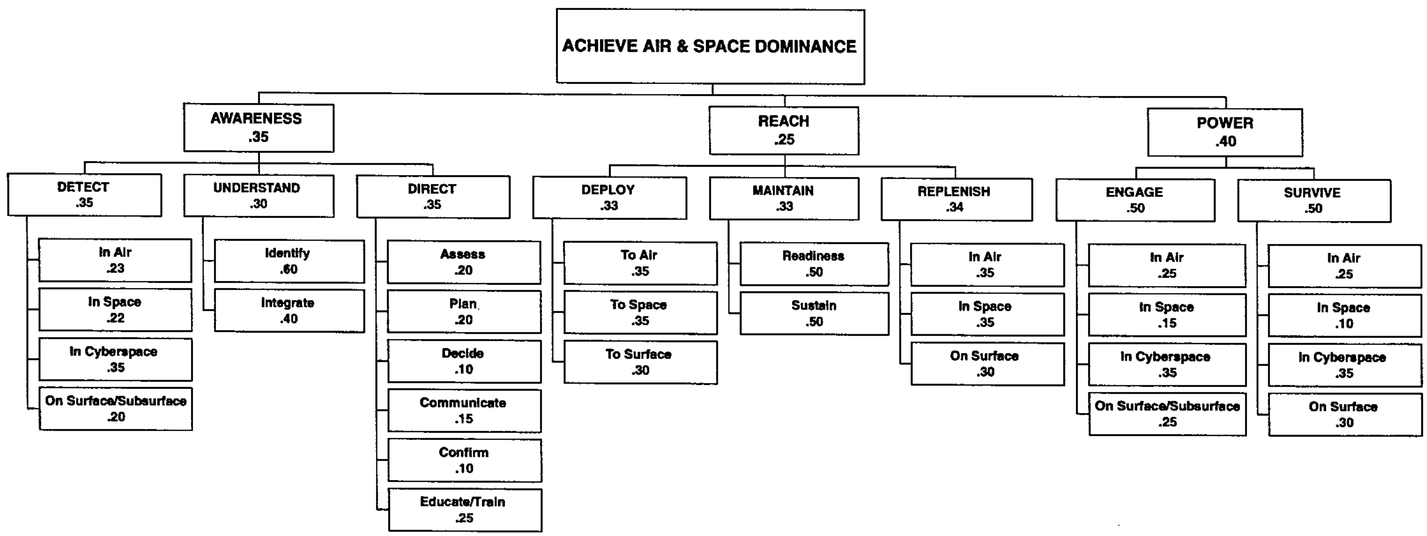


Figure C-7. Alternate Futures Weights—Halfs Future

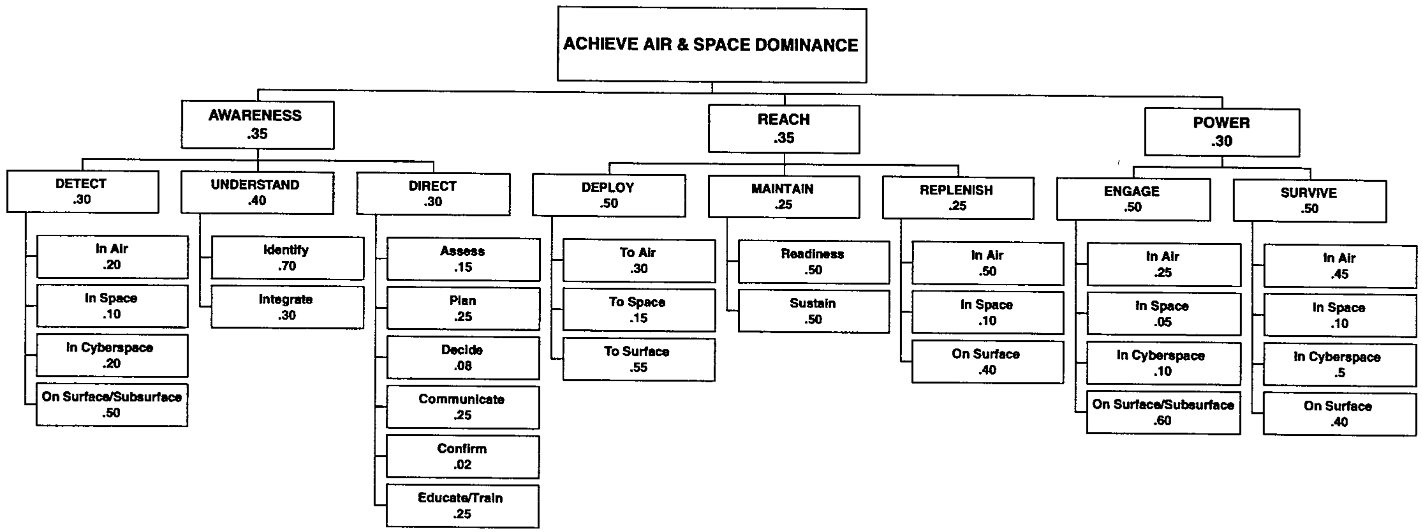


Figure C-8. Alternate Futures Weights—Gulliver's Future

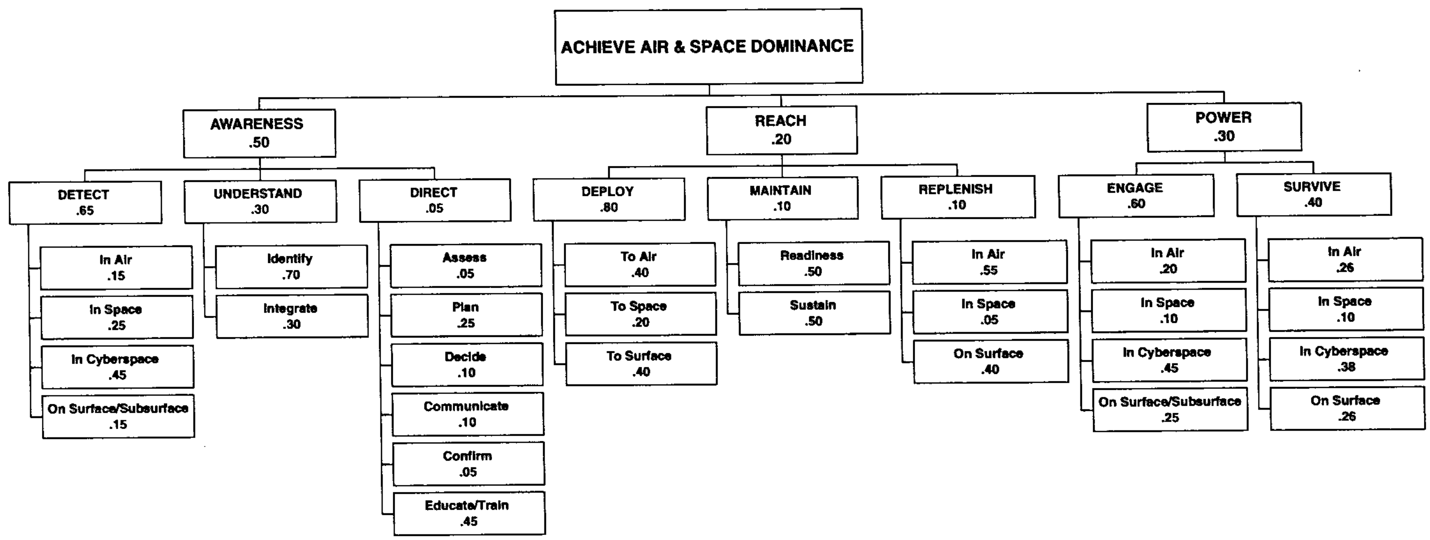


Figure C-9. Alternate Futures Weights—Zaibatsu Future

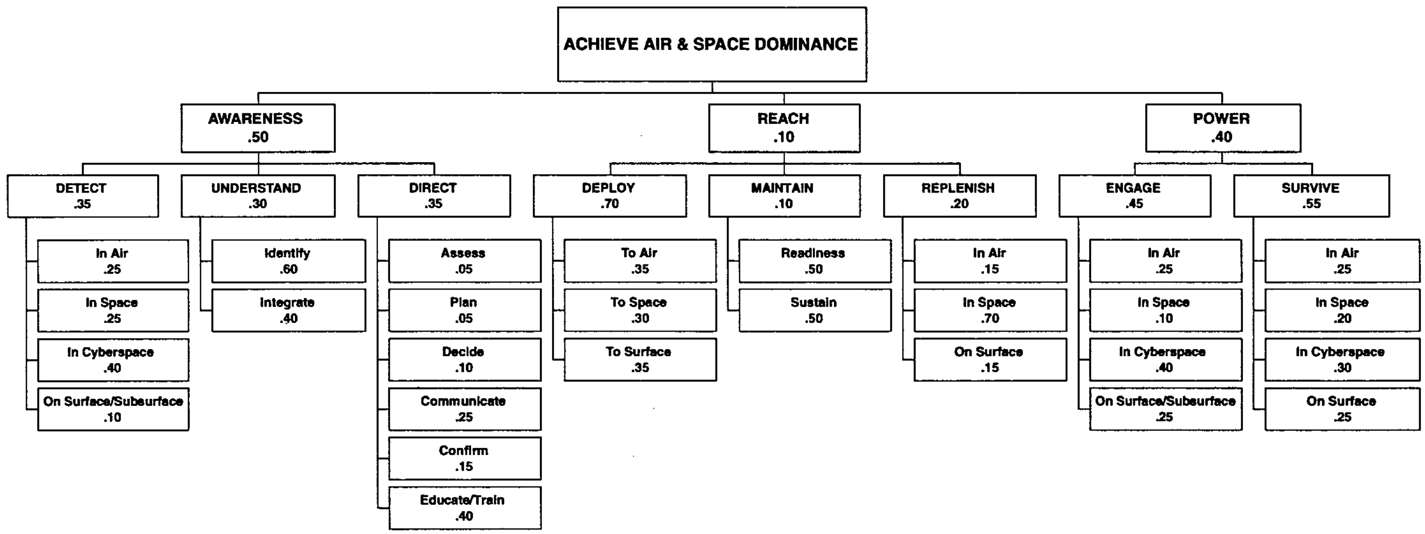


Figure C-10. Alternate Futures Weights—Digital Future

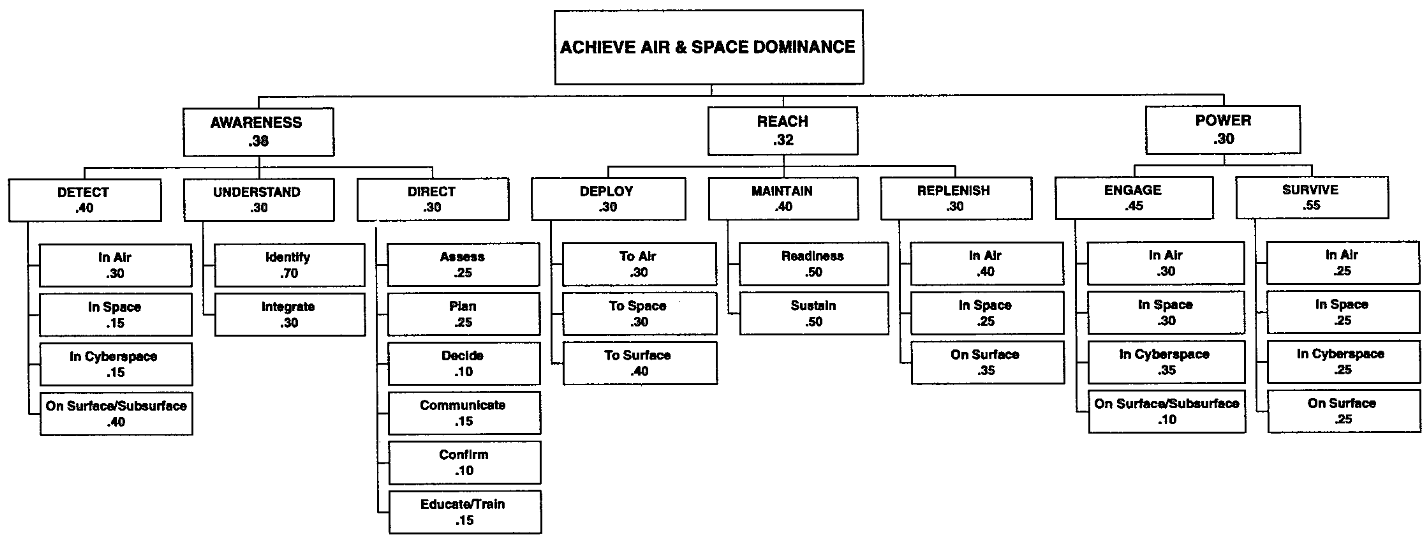


Figure C-11. Alternate Futures Weights—Khan Future

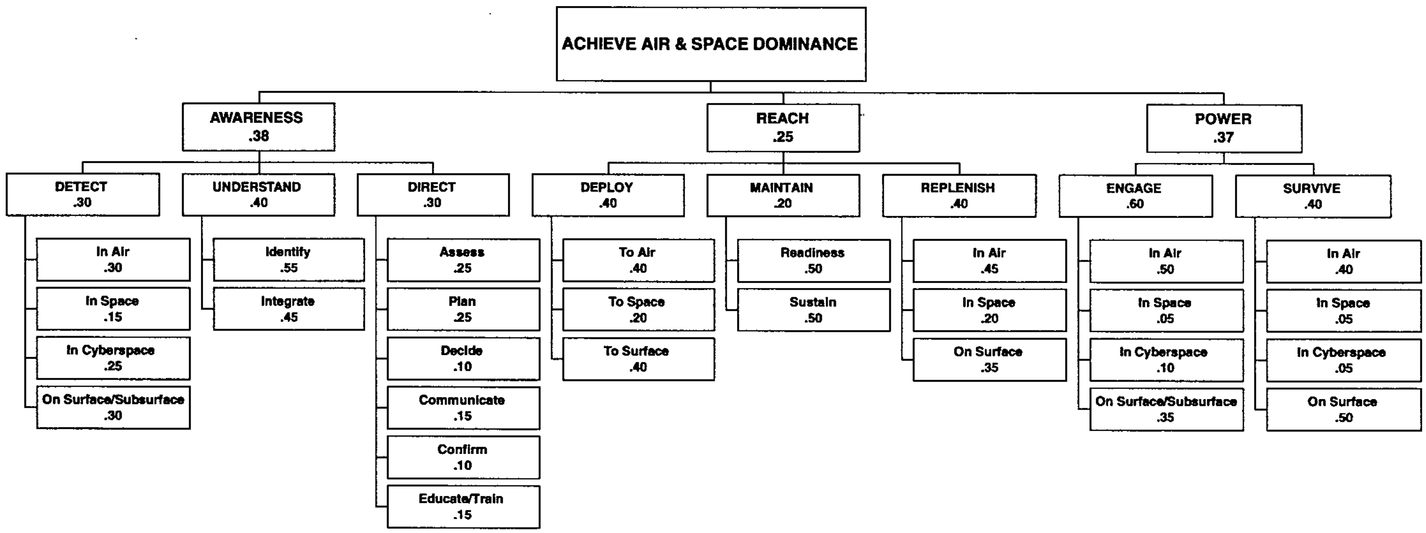


Figure C-12. Alternate Futures Weights—2015 Future

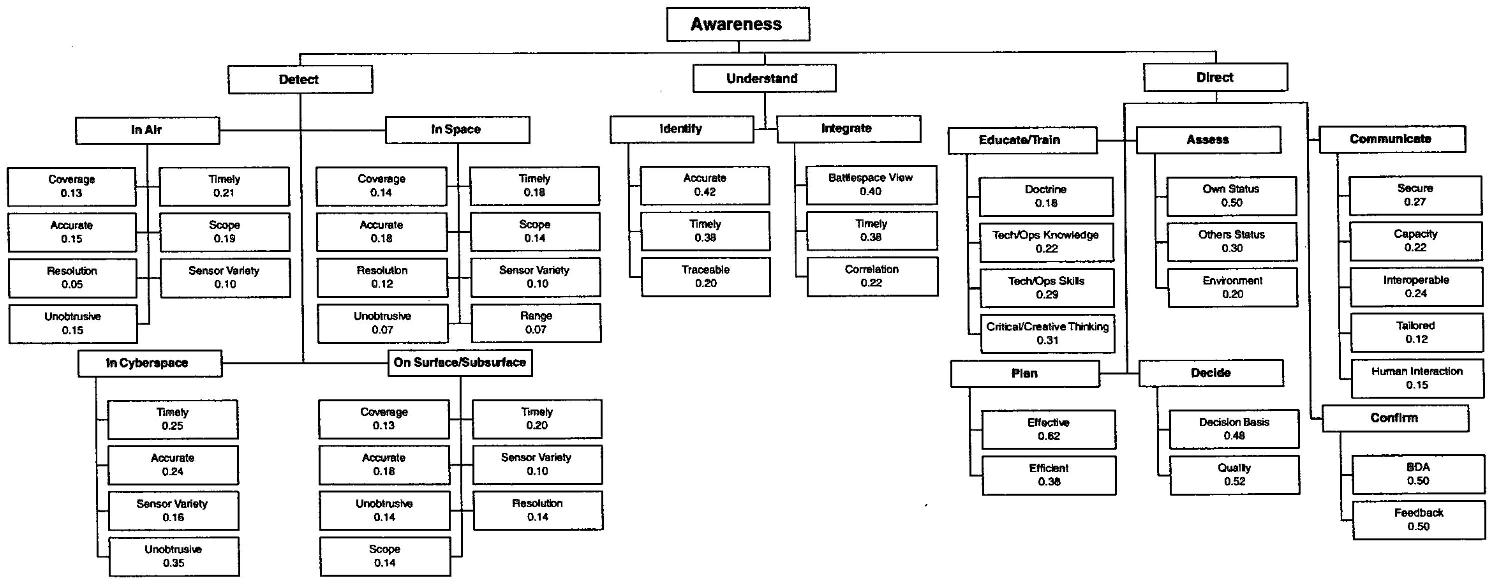


Figure C-13. *Awareness* Force Quality Weights

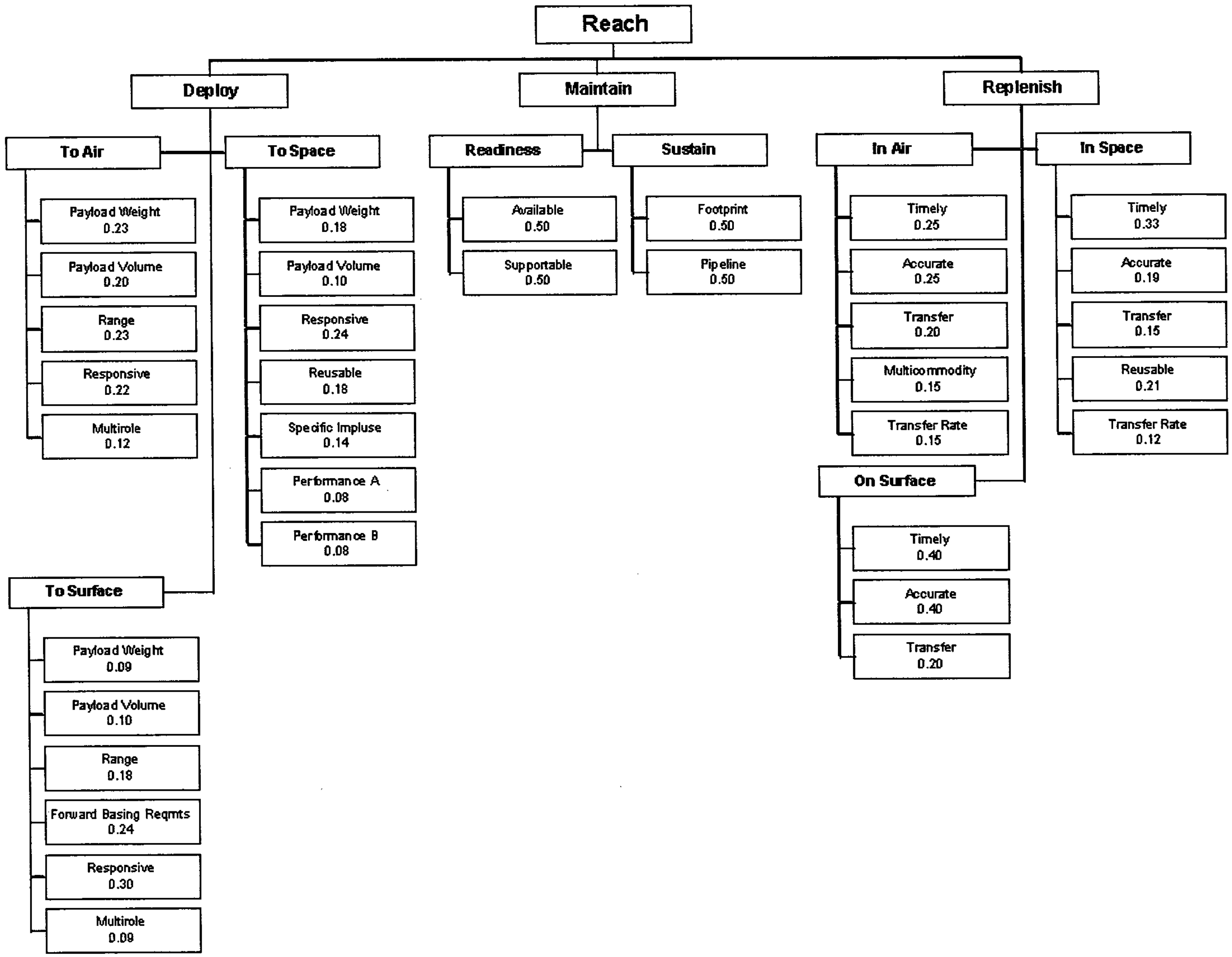


Figure C-14. ***Reach*** **Force Quality Weights**

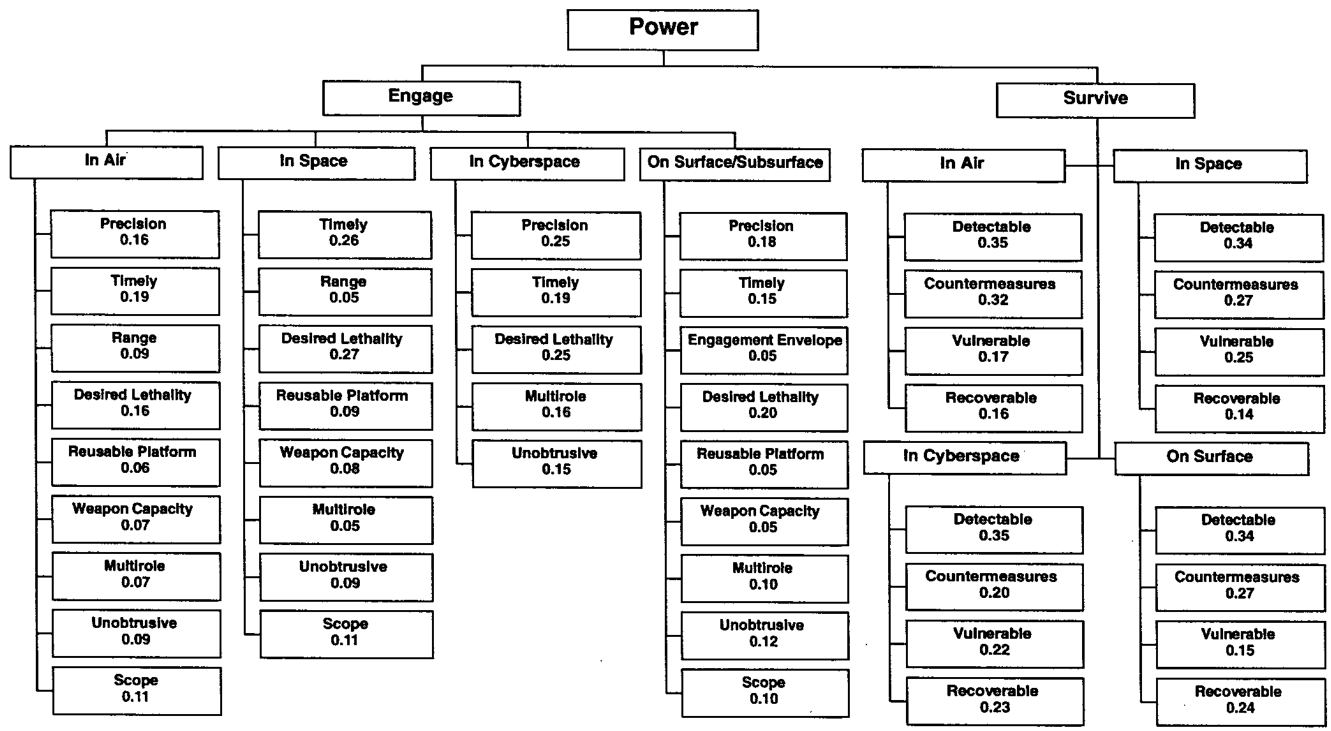


Figure C-15. ***Power*** **Force Quality Weights**

Appendix D

Technology Model

This appendix contains a description of the leveraging technologies identified during the course of system analysis. The technology names, numbering convention, and descriptions contained in the Military Critical Technologies List (MCTL) served as the basis for the ***2025*** Technology Model. Descriptions of three technology areas not fully developed in the MCTL (artificial intelligence, other propulsion, and other sensors) were developed by the Analysis team and inserted into the ***2025*** Technology Model (fig. D-1 and fig. D-2).

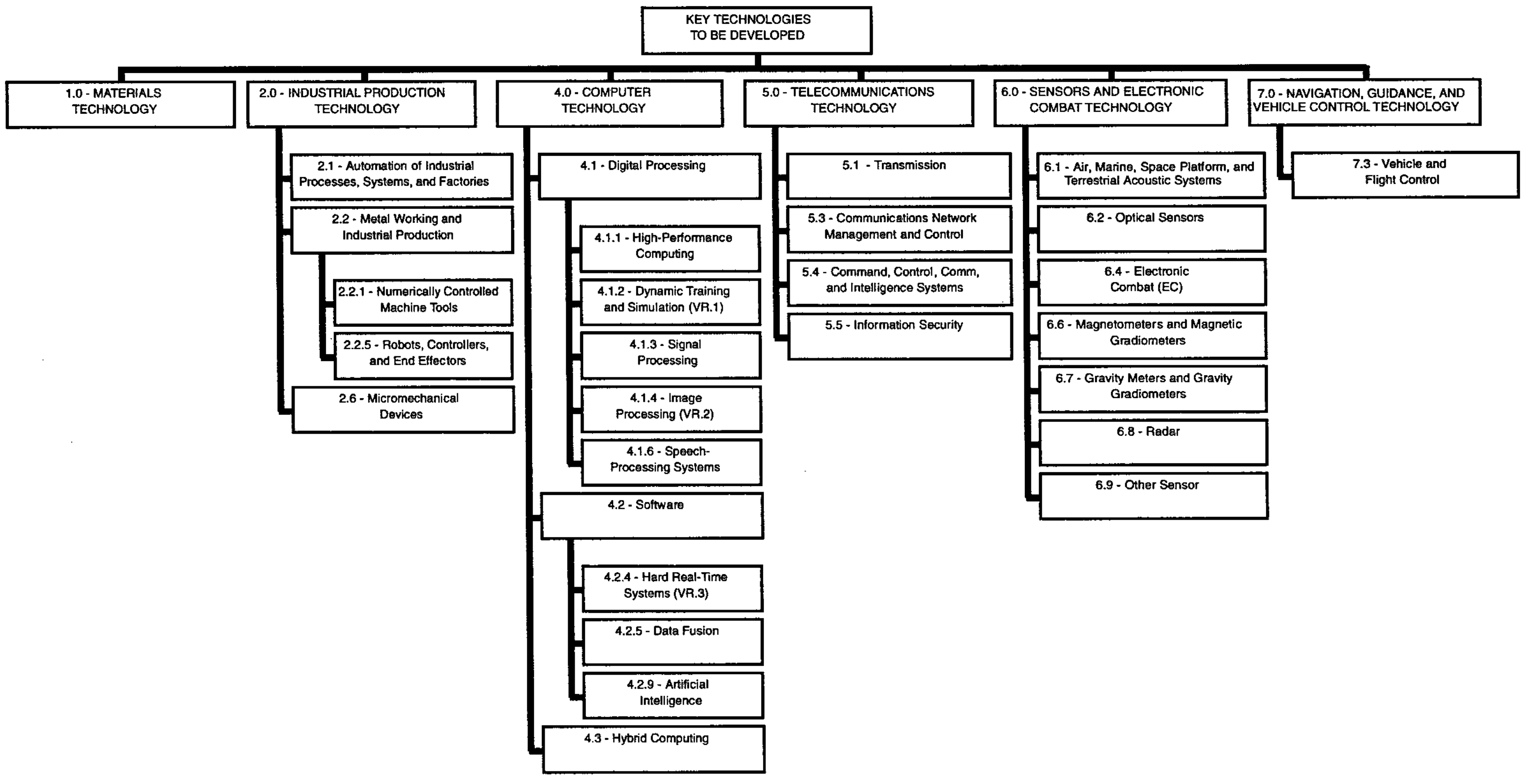


Figure D-1. Technology Model—Part I

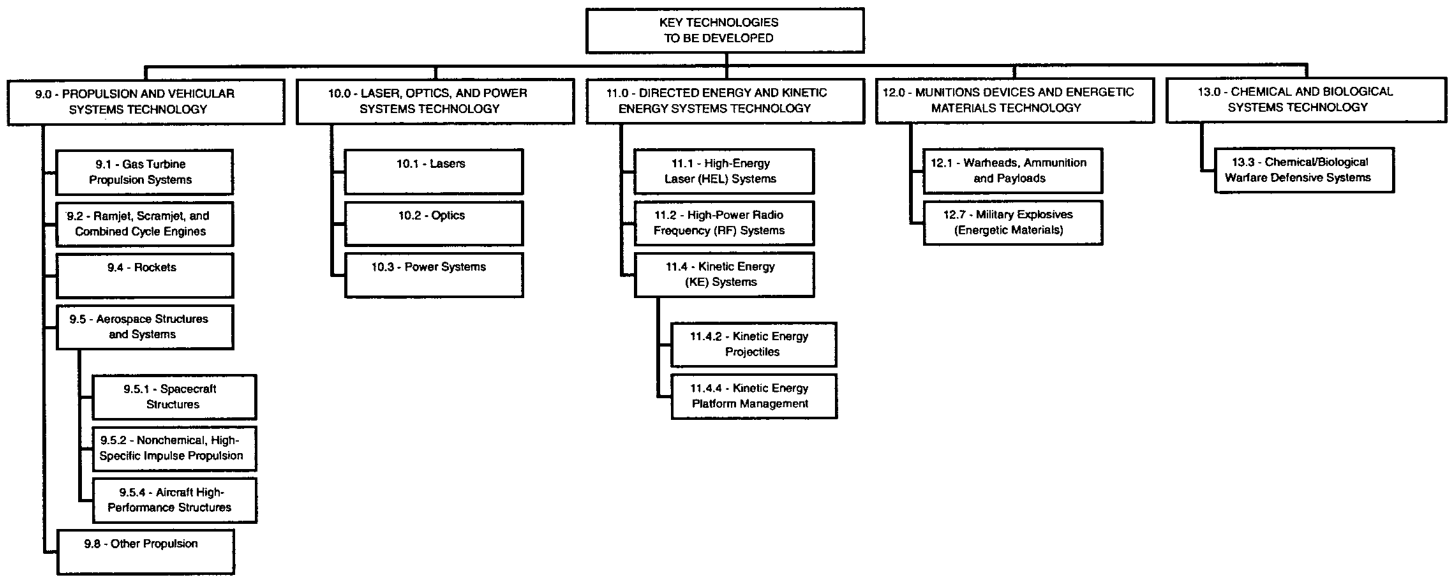


Figure D-2. Technology Model—Part II

Level 1 Technologies

1.0 Materials Technology

This section covers specific dual-use, multiapplication materials and technologies. The metallic, ceramic, and composite materials are principally related to structural, load-bearing functions in aircraft, spacecraft, missiles, surface, and undersea vehicles and in propulsion devices. The selected polymeric materials provide seals and sealants for containment of identified fluids and lubricants for various vehicle and devices, as well as the critical matrix for composites. Selected specialty materials provide critical capabilities that exploit electromagnetic absorption or magnetic or superconductivity characteristics.

2.0 Industrial Production Technology

Production technology includes the facilities, equipment, tools, information systems, and infrastructure for production enterprise. Elements of this technology include automation of part production and assembly, equipment and process tools, real-time planning and control systems, modeling and decision technologies, and the underlying information systems that enable use of the technology. The equipment and technologies of concern in this section support the conversion of raw and semifinished materials into products or components thereof through a sequence of steps which include production design and engineering, manufacturing, and quality inspection and testing. The steps involve computer aided design (CAD)/computer aided manufacturing (CAM), complete factory design, and automation as well as needed technologies for the development and production and integration of the implementing machines, equipment, tools, and software. Technology, software, equipment, and plants for material removal, forming, joining, inspection, coating, measuring, and other generic development and production processes and important components for these production equipments are included. Bearings which are key components not only for production equipment but also for hardware are covered here because of their generic nature and unique industrial base.

4.0 Computer Technology

Existing computer development and production technologies span a wide segment of products, some of which are not practical to control. In this category are products known to be obtainable from multiple sources that are readily accessible outside the US. These products may be decontrolled, but the development and production technologies of embargoed computer products should remain under control. Computers in this section are broadly categorized as digital, hybrid, and advanced. The digital computer classification encompasses primarily those computers whose performance capability exceed certain minimums, including those optimized for signal processing and image processing. A discriminating criterion for this entire category is the ability to do sensor-based processing in real time. Hybrid computers are the amalgam of analogue and digital computers that collectively perform certain computational tasks much faster than on digital computers. Advanced computers are based on technology and structure differing from both digital and hybrid computers. Their performance exceeds that of either digital or hybrid computer technology.

5.0 Telecommunications Technology

This section covers technology for telecommunication equipment used to transfer voice, data, and record information. It encompasses technologies for transmission equipment operating over wire, coaxial, or optical fiber cable or using electromagnetic radiation; radio-transmitting and receiving equipment, including radio telephone, cellular radio, radio

relay and satellites; optical fiber and accessories for information transmission and optical fiber manufacturing equipment; and stored program controlled circuit and packet-switching equipment and networks. Information being exchanged is predominantly in digital form for text, graphic, video, and databases. This format permits the application of security as required. The cryptographic equipment to ensure secrecy for communications, video, data, or stored information and the software controlling or computers performing the functions of such cryptographic equipment are covered.

6.0 Sensors and Electronic Combat Technology

This section covers all sensor types (except chemical and nuclear) that are of military interest. The types include technologies for acoustics, optical sensors, cameras, radar and identification, gravity meters, magnetometers, and associated gradiometers. This section contains a subsection on electronic combat technology since these systems are so closely associated with sensors.

7.0 Navigation, Guidance, and Vehicle Control

This section encompasses technologies for both autonomous and cooperative positioning, coordination, and control of military force elements. Included are technologies for flight management, vehicle guidance, and control. In essence, these technologies are closely coupled and overlap depending on application. Navigation is defined as obtaining the present condition or state of the vehicle from sensed values of position and motion. Navigation is subdivided into inertial-based and position (radio)-based subsections. Guidance systems integrate these conditions and produce vehicle control responses.

9.0 Propulsion and Vehicular Systems Technology

Specific technologies and hardware discussed herein relate to aerogas turbines and diesel engines, particularly those that improve fuel efficiency and power output per pound of engine weight or engine cube and extend engine life; the leading edge technologies associated with such near-earth, exoatmospheric super, and hypersonic flight propulsion systems as Ramjet, Scramjet, and combined cycle engines and liquid and solid rockets; and, the critical technologies associated with the vehicle structures and systems for which the above propulsion systems are usually provided.

10.0 Laser, Optics, and Power Systems Technology

This section covers dual-use technology for lasers, optics and power systems. It covers both high-energy laser (HEL) and low-energy laser (LEL) systems. Optical technologies encompass optical materials, optical filters, optical components for both LEL and HEL applications, optical computing and photonics for instrumentation and signal processing, and large optics for space surveillance applications. Nonlinear optics for beam phase conjugation and image enhancement applications, shared apertures for both directed energy/high-energy lasers (DE/HEL) weapons and space tracking applications, as well as cooled laser optics for both active and passive cooling applications also, are covered. Power systems covered include energy conversion and storage, generation, conditioning, control, and distribution of electrical power for both one-shot, continuous, and pulsed applications.

11.0 Directed Energy and Kinetic Energy Systems Technology

Directed energy (DE) and kinetic energy (KE) technologies can incorporate one or more of the following: laser systems; charged and neutral particle-beam systems; radio frequency (RF)

systems, or kinetic energy systems. This section includes technologies required to generate electromagnetic radiation or particle beams and to project that energy or particle to a target where it will perform interference with system functions, destruction, degradation, or system abort. This section also covers technologies required to impart a high velocity to a mass such as those used in KE systems and direct it to a target.

12.0 Munitions Devices and Energetic Materials Technology

Munitions devices covered by this section are limited to those for conventional systems, to the integration of munitions/weapons subsystems into effective operational systems, and to components that are acted upon by energetic materials or that act on energetic materials. Also covered are energetic materials and fuels technology and the precursors that are necessary for their manufacture. *Energetic materials* is the collective term for high explosives, propellants, and pyrotechnics.

13.0 Chemical and Biological Systems Technology

Chemical and biological technologies cover the following areas: (1) chemical and biological systems and technologies for developing toxic chemical, biological, and toxin agents and their dissemination and delivery; (2) items for detecting, warning, and countermeasuring; and (3) a specific set of advanced biotechnologies that are of explicit military importance and embody critical or unique capabilities.

Level 2 Technologies

2.1 Automation of Industrial Processes, Systems, and Factories

Modern industrial facilities are applying automation technologies increasingly to achieve integrated factory control systems. The technologies of concern in this section support a distributed or hierarchical approach to factory automation consisting of the development, use, and production of key-technology elements and the integration and implementation of these elements to provide automated control of industrial systems. A primary vehicle for transfer of critical technology (know-how) addressed in these sections is access to extractable information in software. Such know-how includes engineering design and manufacturing process information embedded in software (e.g., control algorithms, models, and knowledge-based CAD/CAM products) embodying critical technologies. This information can take a variety of forms, including empirically validated engineering design databases or expert systems designed for CAD/CAM or industrial automation applications.

2.2 Metal Working and Industrial Production

This subsection covers the technology for the general category of machinery and equipment used for the production of systems and components. The equipment described are needed to produce other production equipment, as well. The individual pieces of machine tools, machinery, and process equipment provide the foundation for the manufacturing level of a plant. Most incorporate or are equipped with electronic controllers to assist in providing accuracy, flexibility, and speed to the production process. The individual machines may be integrated into work stations or cells to communicate and be integrated into higher level industrial automation systems.

2.6 Micromechanical Devices

This subsection covers the production and technologies for the manufacture of micromechanical devices (also known as micromachines, microrobots, and microsensors) and their components. Focus is on scale and miniaturization of micromechanical technology for structural components using technologies characteristic of microelectronic production. The three major areas of concern include (1) manufacture and inspection of parts with nanometer range tolerances; (2) manufacture and inspection of integrated micromechanical and microelectronic systems with nano meter range tolerances; and (3) assemblies of these parts into subcomponents and systems which require submicrometer and finer tolerances. Current state-of-the-art machine tools can make/produce parts with tolerances (accuracies of 0.5 to 1 micron [1,000 nanometers]. Specialized precision machine tools can produce parts in the 200-nanometer range. Special polishing processes can produce surface finishes of 10 nanometer surface roughness or better. Technology and equipment for producing such large parts as laser mirrors, other optics, molds for precision casting, suspension systems, hydraulic system components, accelerometer, gyro, missile guidance, and inertial navigation components which require nanometer tolerances for surface finish and form fall within the scope of this section.

4.1 Digital Processing

High-performance digital computing is an area of critical concern. The development, production, service, and operational use of high-performance digital computing are also of concern. In addition to addressing these functions, the section also focuses on specific designs, key storage equipment, and critical applications.

4.2 Software

The broad categories in this subsection address software directly applicable to military activities; software engineering used to support the development, operation, and maintenance of other software; and general-purpose software that has a dual role in supporting military data processing.

4.3 Hybrid Computing

Hybrid computing technology provides the functional integration of digital and analogue processing primarily for dynamic simulation of complex physical systems. Dynamic simulation (hardware in the loop) is an essential step in the development of virtually all tactical and strategic guided weapons. Dynamic scene generators that provide computer generated imagery for the testing and training of infrared seeking sensor systems are integral to the development of guided weapons employing such features. Hybrid technology realizes both the inherent speed of analogue processing and the programmability and accuracy of digital processing required for weapon design and testing.

5.1 Transmission

This subsection covers technology for telecommunications transmission equipment and components used for transfer of voice, data, record, and other information by electromagnetic means either through atmospheric, exoatmospheric, or subsurface (water) media or through metallic or fiber optic cable. Controllability is of concern since telecommunications technologies below the control level may suffice for transfer of the telemetering information.

5.3 Communications Network Management and Control

Communications technology covered in this item is highly dependent on the automation of the monitoring and controlling functions within the communications network. The monitoring and controlling functions are combined in separate systems capable of working over a widely dispersed geographical area with equipment using various transmission media and switches using common channel signalling. These systems provide a centralized control capability to configure transmission equipment to optimize networks for loading and failures; configure switches and routers to optimize the call distribution within a network; and alter network configurations and routing information to provide special network service features. The information transferred using transmission control protocol/internet protocol (TCP/IP) or similar protocols ranges from basic integrated services digital network (ISDN) and fractional multiplexers up to 45 Mbit/s and network access controllers operating at a digital transfer rate up to 33 Mbit/s with local area networks (LAN)/wide area networks (WAN).

5.4 Command, Control, Communications, and Intelligence Systems

Integrated C^3I systems are fabricated combinations of platforms, sensors and weapons, software and data-processing equipment, related communications subsystems, and user-system interfaces specifically designed for the control of US armed forces and weapons systems. Command, control, communications, and intelligence systems are integrated combinations of military command information processing, communications network, and intelligence-gathering subsystems (including surveillance, warning, and identification subsystems) that make up the US C^3I systems. These combined technologies support US authorities at all echelons with the integrated C^3I systems that provide the timely and

adequate data required to plan, direct, and control US military forces and operations in the accomplishment of their missions.

5.5 Information Security

Information security includes the means and functions controlling the accessibility or ensuring the confidentiality or integrity of information and communications, as well as the availability of resources, excluding the means and functions intended to safeguard against malfunctions.

6.1 Air, Marine, Space Platform, and Terrestrial Acoustic Systems

Most marine-sensing systems use sonars which employ acoustic signals (sound waves) to locate underwater objects and features. Sonars are termed active when sound is generated by the system for the purpose of echo ranging on a target and passive when listening to the sound radiated by the target. Sonar systems are the principal sensors used for antisubmarine warfare (ASW), mine warfare, and deep-sea salvage for the purpose of detecting, classifying, identifying, locating, and tracking potential underwater targets. Additional uses are undersea mine and torpedo homing and activation, depth sounding and bottom mapping. Sonars are used commercially for locating fish and other objects in the ocean, for seismic exploration at sea, for petroleum and mineral exploitation, and for academic studies. Most terrestrial (land-based) seismic systems employ sound waves to locate features in the earth's crust for geophysical prospecting. All acoustic seismic systems are active. Acoustic vibrations are also a critical issue for space platform stability. Aircraft and space sensors and optical systems require stabilization from acoustic coupling due to propulsion and power generation equipment acoustic noise.

6.2 Optical Sensors

This subsection covers equipment and components that are sensitive to emissions in the electro-optic (EO) portion of the electromagnetic spectrum, (ultra-violet, visible, and infrared in micrometers: UV 0.01-0.4, VIS 0.4-0.8; IR 0.8-30.0) and support equipment therefor. Applications include seeker heads, night vision imaging, intrusion detection, medical diagnosis, and earth resource analysis.

6.4 Electronic Combat

This subsection includes electronic support measures (ESM), electronic countermeasures (ECM) and electronic countercountermeasures (ECCM), all of which are part of electronic combat. ESM involve actions taken to search for, intercept, identify, and locate radiated electromagnetic energy. ECM involves actions taken to prevent or reduce an enemy's effective use of the electromagnetic spectrum. And ECCM involves actions taken to ensure friendly effective use of the electromagnetic spectrum despite the enemy's use of ECM.

6.6 Magnetometers and Magnetic Gradiometers

Magnetic sensor systems detect and display the presence of a magnetic field and measure its magnitude and/or direction. Some magnetic sensors are sensitive to their orientation with respect to the vector components of the magnetic field in which they find themselves; others are not. Some are capable of measuring the absolute level of an ambient magnetic field; others can only measure variations. Magnetic sensor systems are often configured to detect the spatial variation of the magnetic field intensity, that is, the gradient of the magnetic field intensity. In this mode, they are called magnetic gradiometers. Magnetic gradiometers can

consist of two magnetometers or consist of a single intrinsic sensor. Compensation for background noise and processing of the sensor data are required to obtain optimal performance in a given application.

6.7 Gravity Meters and Gravity Gradiometers

Gravity meters can be used in a static or moving base mode to measure gravity magnitude. The gravity gradiometer, used in the same modes as above, is used to measure gravity gradients. Gravity data is used to estimate vertical deflection and other gravity field components. An absolute gravimeter is usually operated at a fixed installation by the accurate (better than 10^{-8} seconds) timing of a falling weight or of a swinging pendulum. Due to the improvement of timing devices and instrumentation, the freely falling body method is currently favored. Distance accuracy measurement of better (or less) than 0.5 micrometer is needed to obtain an accuracy of 1 m Gal with a fall of 1 or 2 m. Previously, a large number of oscillations of a pendulum was the preferred absolute gravity-measuring method. Astrolabes are used to measure astronomic positions which in conjunction with geodetic position are used to compute deflection of the vertical. Whereas gravity mapping is required over a significant area to calculate deflection of the vertical, the astrolabe allows determination at a single point. These sensors can be used commercially to assist in the exploration for such natural resources as oil, gas, or minerals. Since gravity and spatial accelerations are not separable, inertial navigation and guidance systems require compensation based on knowledge of the gravity field. Gravity meter accuracy is essential for siting and initializing ballistic missiles and other long-range unaided inertial military system applications.

6.8 Radar

This subsection covers RF and laser radars, including identification, recognition, and classification technology. Radar has many military and civil/commercial uses. Applications of radar include surface and airborne surveillance, fire control, air traffic control, and meteorological analysis. Identification and classification technologies involving noncooperative targets are a matter of heavy development effort with some real promise of success as data-processing speeds and digital memory hardware ramifications allow massive processing in small packages.

6.9 Other Sensor

This subsection covers sensor types not specifically covered in other subsections.

7.3 Vehicle and Flight Control

This item covers the technologies that collect, integrate, and analyze data from multiple onboard aircraft sensors and instruments, through use of high-speed buses and data-processing units and provide military aircraft, space vehicles, and ground combat vehicles with flight movement control systems that optimize their performance for specific mission profiles. These guidance and control management systems convey the directions of the operator by providing the optimum control information to the vehicle for the situation at the time of operator input (avoiding over or under control). Since vehicle and flight control systems can only operate with the real-time collection, analysis, and feedback of data, the systems depend upon technologies associated with state-of-the-art sensors.

9.1 Gas Turbine Propulsion Systems

This subsection covers gas turbine development, production. and use technologies, particularly those related to extending engine life and performance. This section also includes advanced engine test facility technologies and hardware and full authority digital engine controls, diagnostic equipment, engine structures, and materials. Technologies of concern support higher thrust-to-weight ratios and higher internal operating temperatures and variable cycles, with increased fuel efficiency and longer operating life.

9.2 Ramjet, Scramjet, Combined Cycle Engines

Ramjet/Scramjet/combined cycle propulsion systems provide flight speed capability for air-breathing propulsion systems to Mach 25. Combustion can take place either subsonically (Ramjet), supersonically (Scramjet), or both (i.e., dual-mode subsonic/supersonic combustion). Two types of Ramjet engine configurations are the podded Ramjet and the integral rocket Ramjet (IRR). Many types of combined cycle engines are being studied, however, the most common types include the air-turborocket or air-turbojet, turboRamjet, liquid air cycle engine, dual-mode Ramjet/Scramjet engine, and turborocket Ramjet engines. Several operational Ramjets currently have been limited to military applications and flight speeds up to Mach 4. There are no currently operational combined cycle engine types in the United States. Future applications of the Ramjet and combined cycle engines include hypersonic missiles capable of flight speeds up to Mach 6 and hypersonic aircraft and advanced space launch vehicles for either military or commercial use capable of flight speeds up to Mach 25. Technologies of concern are those for the design and production of the Ramjet and technologies unique to the integral rocket Ramjet and combined cycle engines. This item covers both fixed- and variable-area inlets for Ramjet and combined cycle engines, including installed inlet performance analysis of relative mass flow/pressure recovery and internal flow field analysis; high-density fuels and fuel delivery systems used to permit Ramjet and Scramjet vehicles to operate up to Mach 6-10. It also includes the tank/vessel structure, insulation, valve/control devices for fuel metering, and the fuel injection devices. Finally, this item includes flame-holder/combustion aids, insulation systems, igniter systems, transition devices (from rocket to Ramjet operation), and nozzle design. Combustor insulation includes both short-life ablator systems and longer life nonablating systems, as well as systems which include fuel or air cooling.

9.4 Rockets

The technologies discussed here focus on the propulsion of rockets and missiles by either solid, liquid, or hybrid propulsion motors. The technologies of concern are those associated with providing more efficient propulsion through better propulsion control, more lightweight motor hardware, more efficient subsystems, and better development and production processes.

9.5 Aerospace Structures and Systems

Advances in structures technology are expected to improve aircraft and spacecraft performance significantly. Incorporation of new materials and design concepts in aircraft structure will expand aircraft operating envelopes, reduce observability, and improve survivability to ballistic and laser threats. Incorporation of new materials and structures concepts into spacecraft will significantly reduce weight, provide increased precision for greater mission performance, reduce cost, improve producibility, and contribute to improved survivability to natural and man-made threats. New materials offer high strength to weight,

stiffness to weight, and greater resistance to fatigue and corrosion; high-temperature durability; and increased toughness, moisture resistance, and reformability. Structures-related technologies are vital to systems which play major roles in strategic and tactical warfare missions. Because many problems and technologies related to survivability apply to ground vehicles as well as to aerospace vehicles, survivability of both sets of vehicles is covered in this section.

9.8 Other Propulsion

This subsection covers propulsion types not specifically covered in other subsections.

10.1 Lasers

Technologies applicable to the development and production of lasers and laser systems in the infrared (IR), visible, and ultraviolet (UV) regions of the electromagnetic (EM) spectrum (0.3-0.01 to 30 μm) capable of achieving significant levels of energy or power are covered. Lasers consist of the laser hardware (the device) and laser medium (host material), mirrors, and other optical components that form the laser oscillator cavity. Lasers may operate in a continuous, repetitive, repetitive burst, or single-pulsed mode depending on the application and requirements. Laser systems incorporate such components as amplifier stages, frequency conversion components, Raman cells, multiple wave mixing components, or other major elements in addition to the laser oscillator.

10.2 Optics

Optical technologies encompass optical materials, optical filters, optical components for both low-energy laser (LEL) and high-energy laser (HEL) applications, optical computing and photonics for instrumentation and signal processing, and large optics for space surveillance applications. Nonlinear optics for beam phase conjugation and image enhancement applications, shared apertures for both directed energy/high-energy lasers (DE/HEL) weapons and space-tracking applications, as well as cooled laser optics for both active and passive cooling applications also are covered.

10.3 Power Systems

This subsection covers technologies for nonnuclear energy conversion and electrical power generation, energy storage, and power conditioning and pulsed power systems and power control and distribution. Technologies related to devices and components and thermal management and system integration technologies are also included. Well-regulated and high-power-density power supplies are a key supporting technology for reliable computing and in telecommunications and information systems.

11.1 High-Energy Laser Systems

This subsection includes those technologies required to generate laser beams and project them to a target where they will perform destruction, degradation, or mission abort. Mission abort includes both temporary interference with the ability of the system to function as well as permanent degradation which prevents proper system function. This class of technology is called high-energy laser-directed energy. Included are those technologies required to generate, project, and couple the beam while tracking the target and aim point and propagating through the atmosphere or a space environment. This section also includes the technologies required to implement and integrate them into a DE system. HEL systems are capable of generating intense beams (20 kW or greater average power, 1 kJ or more energy

per pulse) in the infrared, visible, and ultraviolet regions of the electromagnetic spectrum (0.3 to 30 μm). Depending upon the laser type, the system may operate in a continuous, repetitive burst, or single-pulsed mode. HEL systems consist of the laser device, mirrors and other optical components that form the laser cavity. HEL/DE systems consist of the laser plus a control subsystem for directing the beam to a target and other optical components used to stabilize or improve the laser beam quality.

11.2 High-Power Radio Frequency Systems

High-power RF systems project intense power in either pulsed or continuous waves. In some contexts, such technology and systems are known as high-power microwave (HPM). These systems consist of sources capable of generating sufficient RF power, components for modulating the power, and antenna arrays which can direct the energy to a target. Current frequencies of interest lie between 0.1 and 1,000 GHz. Power levels of interest include peak power of 100 megawatts or more, single-pulse energy of 100 J or more, and average power of more than 10 kW. Sources which can operate in the aforementioned regimes and are amenable to weaponization are critical to the development of RF weapons systems. The principal technologies related to HPM are pulsed power and those concerned with the protection of targets from RF radiation.

11.4 Kinetic Energy Systems

Kinetic energy technologies of interest are those required to propel projectiles to higher velocities (greater than 1.6 km/sec) than are typical of projectiles from conventional gun or rocket systems and to obtain an appropriate combination of properties including shape, size, density, and ductility at that velocity. Technologies for precision pointing, tracking, and launch and for management of launch platforms are also of concern.

12.1 Warheads, Ammunition, and Payloads

This subsection covers the technology, materials, and equipment necessary to develop, produce, and integrate conventional, improved conventional, precision-guided, or smart munitions for air-, sea-, or ground-launched systems including projectiles, mines (sea and land), bombs, fuel-air munitions, mortar rounds, torpedoes, and missile and rocket warheads.

12.7 Military Explosives (Energetic Materials)

This subsection covers technology to develop and produce the ingredients of high-explosive, propellant, and pyrotechnic formulations and to use the ingredients in the development and production of militarily useful formulations. Materials, equipment, and processing principles necessary for manufacturing facilities draw on developments within the commercial chemical processing industry, and some are widely available chemical products. However, the listed materials are primarily, if not uniquely, used for the manufacture of warheads, propulsion systems, and the guidance and control systems of munitions controlled under the US munitions list (USML), international munitions list (IML) and the missile technology control regime (MTCR). After the materials (ingredients) have been produced in bulk, technology is required to develop, blend, and formulate compositions to give them the characteristics necessary for particular applications; to fabricate charges or to load them in selected munitions systems; and to test the charges or systems to assure that the performance objectives have been met. Coverage is limited to the listed substances and to other substances or compositions that meet specified performance criteria. It includes both

theoretical (computational) and empirical methods of defining required compositions and properties and chemical and physical processes for incorporating these in military systems. Commercial application of the formulation, fabrication, and test technology is limited, but the principles and the equipment, facilities, and software also can be used to optimize and produce commercial explosive products. The development of formulations and the production of charges are also necessary for commercial devices that are used in blasting, oil exploration, and oil well stimulation; for explosive-forming of metals and compacts; and for space vehicles.

13.3 Chemical/Biological Warfare Defensive Systems

This subsection covers the technologies and materials relative to defend against chemical and biological warfare (CBW) and biopolymer-based detection and warning systems. Defense against CBW entails detection and warning, individual and collective protection systems, and countermeasures, including decontamination.

Level 3 Technologies

2.2.1 Numerically Controlled Machine Tools

This item includes numerically controlled (NC) units, motion control boards, NC machine tools for turning, milling, and grinding, nontraditional machine tools, and components for material removal machines. NC machining provides the ability to produce repeatedly parts of accurate dimensions containing complex geometry, allowing designers to specify components closer to desired functional shape with fewer manufacturing concerns. Repeatability and accuracy of parts lead to the higher performance ratings and endurance of US equipment.

2.2.5 Robots, Controllers, and End Effectors

This item covers industrial and military smart robots, controllers and end effectors capable of employing feedback information in real-time processing from one or more sensors to generate or modify programs or program data. These robots are multifunctional manipulation devices capable of positioning or orienting parts, tools, or other devices through variable movements in three-dimensional space and thus would have three or more closed or open-loop servo devices. They have user accessible programmability by means of teach/playback or off-line computer or programmable logic controllers. This technology is critical to the delivery of essential numbers of required quality systems to the battlefield. It applies in industrial processes and in the battlefield. Robotic technology is used in industry to provide the quality and quantity of goods needed while providing for personnel safety and industrial flexibility to meet changing needs. Radiation-hardened robots are used in nuclear reprocessing and nuclear production reactor activities. They may be used in nuclear facilities to reduce occupational radiation exposures.

4.1.1 High-Performance Computing

The highest performance digital computers currently in use are composed of vector and scalar processors maximized for performance with some achieving clock cycles under five nanoseconds. Logic and memory device technology appears to limit individual processor clock cycle advances to approximately one nanosecond. Interconnecting a multiplicity of these units into coupled parallel combinations continues to yield performance gains with 16 vector processors being generally the maximum size envisioned. A significantly different parallel processing architecture involves the interconnection of conventional digital processing elements. Medium parallel combinations range from an interconnection of 16 to 100 processors using processors composed of work stations or low-end technology devices. Massively parallel computers range from 100 to 100,000 and beyond processor combinations that yield high theoretical performance but encounter difficult interconnection, programming, and use problems. Visualization is a presentation technique aiding in the extraction, analysis, and interpretation of voluminous data sets required for solutions of problems in such fields as astrophysics, geophysics, fluid dynamics, chemistry, structural analysis, and high-energy physics. For large data sets, visualization can only be achieved by a computational environment containing a super computer for modeling, simulation and analysis, a large main frame for data processing and file management, and a dedicated visualization computer with a high-resolution display, large buffers, and high-speed data paths linking components within the environment. Software support allows use of graphic techniques based upon, or in combination with, points, areas, volumes, geometric primitives, wire frames, and color at a frame rate greater than 20 frames per second.

4.1.2 Dynamic Training and Simulation

Techniques that allow operator feedback into real-time control functions that enhance realism by coordinated multisensor operator inputs. They incorporate real-time evaluation of operator/trainee performance and are being used extensively for operator training, maintenance, and repair of a wide variety of equipment.

4.1.3 Signal Processing

Digital computers or assemblies or software characterized by an architectural structure wherein the principal processing elements are optimized for the manipulation of data generally derived from external sensors and from which signals of interest can be obtained are considered to be signal processors. Information is extracted from the signals by employing equipment, algorithms, and software programs. The output of the signal extraction process is subjected to additional analysis and processing from which critical parameters and classifications are determined. The entire computational analysis must be done in real time to be of critical use.

4.1.4 Image Processing

Technology used for acquiring, transferring, analyzing, displaying, and making tactical use of image data in real time or near real time. Of particular concern are those technologies related to implementation of mobile sensors for real-time target acquisition and guidance, processing and displays of large complex data sets, archival storage of imagery data, real-time displays and three-dimensional (3-D) presentation, and data transmission and compression techniques.

4.1.6 Speech Processing Systems

Techniques for analyzing and synthesizing continuous (connected) speech exist in the form of algorithms and special semiconductor devices. Operating hardware is available and improved techniques are under development for synthesizing speech from a digital stream to provide an improved interface between computers and man.

4.2.4 Hard Real-Time Systems

Real-time processing is defined as the processing of data by a computer system to provide a required level of service, as a function of available resources, within a guaranteed response time, regardless of the load of the system, when stimulated by an external event. This definition also applies to hard real-time operating systems that provide a shared set of computer resource management services designed and optimized for supporting such time-critical computer software applications as process control systems, command and control, and flight control. Key functional attributes of real-time operating systems protect and isolate application programs from the effects of errors in other programs sharing the resources and their ability to respond to stimuli in a guaranteed predetermined time.

4.2.5 Data Fusion

Data fusion is the technique whereby multivariate data from multiple sources are retrieved and processed as a single, unified, logical file. It is an integral part of command and control systems with distributed sensors. The range of fusion requirements increases as the need progresses from the missile seekers of an air-to-air missile to the avionics cockpit through various echelon levels to the command center. Intelligent processing is a major ingredient of

all fusion requirements. A significant set of *a priori* databases are crucial to the effective functioning of the fusion process.

4.2.9 Artificial Intelligence

The field of computer science seeking to instill into machines the ability to solve problems through the careful use of knowledge in approaches such as expert reasoning, analysis, analogy (educated guessing), and learning. Vision, natural language understanding, expert systems, fuzzy logic, and neural networks are several subfields of artificial intelligence.

9.5.1 Spacecraft Structures

This item covers specifications for dimensionally stable structures for spacecraft which employ techniques for control of structural distortion, including materials designed for zero coefficient of thermal expansion designs to prevent structural outgassing in orbit and materials that provide high strength and high stiffness. Analysis techniques are used to simulate the dynamic interaction of the structure with the spacecraft control system in lieu of full-scale testing and provide the means to define a design with the required stability characteristics for spacecraft with precision structures, including optical systems and antennas or such large flexible appendages as solar panels.

9.5.2 Nonchemical, High Specific Impulse Propulsion

This item covers low-thrust propulsion devices that can be used for spacecraft station keeping or orbit changes including electrostatic, electrothermal, or electromagnetic propulsion systems. These devices utilize electrical power to accelerate propellant gases to high-exit velocities.

9.5.4 Aircraft High-Performance Structures

This section covers dual-use technology that will improve (1) the performance of current, near-future, and advanced (including hypersonic) aircraft with structures exhibiting improved mechanical and thermal properties as well as lower weight and cost and (2) performance, durability, fatigue life, and acoustic damping of helicopters and other vertical take-off and landing (VTOL), short take-off/vertical landing (STOVL), and short take-off and landing (STOL) aircraft, whose designs involve exposure of aircraft structure to high levels of engine-generated heat and noise. This section covers dual-use technology that will increase structural safety and operational readiness and decrease maintenance and repair costs of aircraft structures. This section also covers military-use technology that will improve the efficiency of repairing battle-damaged composite structures and dual-use technology for repairing composite structures damaged in peacetime service or by maintenance mishap.

11.4.2 Kinetic Energy Projectiles

This item covers technologies for kinetic energy projectiles which can destroy or damage targets through their own kinetic energy derived from their own nonchemical sources.

11.4.4 Kinetic Energy Platform Management

This item delineates technologies necessary to ensure efficient platform management systems for kinetic-energy weapons for both space and ground-based systems.

Appendix E

System Scores

This appendix presents the assigned values of each measure of merit for each system. As described in the "Methodology" chapter, the scoring functions (fig. A-5 through fig. A-32) were used to determine the utility of the systems for each measure of merit; the utilities were then multiplied through the weighted value models (appendix C) to determine the overall system values. Figure E-7 and figure E-8 present the results of this process, which is also shown graphically in the "Results" chapter.

A keyed designator is provided to distinguish measures of merit having duplicate names (e.g., accuracy). Figure E-1 shows the Value Model with this additional keying information.

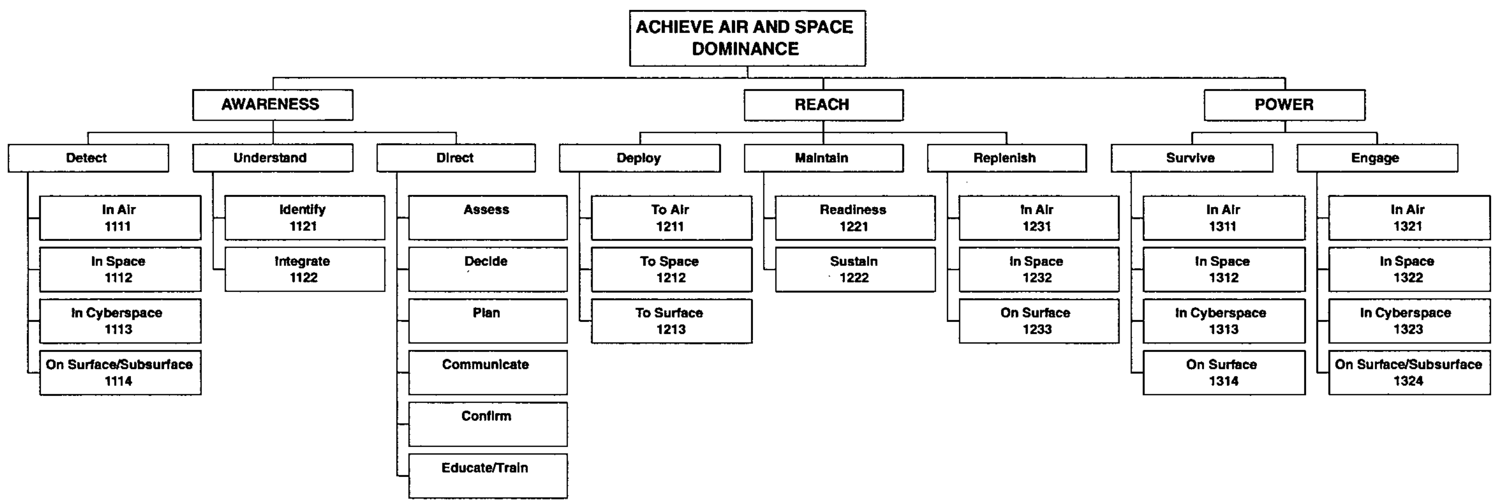


Figure E-1. Value Model—Top Level

	System Name	Coverage 1111	Timely 1111	Accurate 1111	Scope 1111	Sensor Variety 1111	Unobtrusive 1111	Resolution 1111	Coverage 1112	Timely 1112	Accurate 1112	Scope 1112	Sensor Variety 1112	Range 1112	Unobtrusive 1112	Resolution 1112	Timely 1113	Accurate 1113	Sensor Variety 1113	Unobtrusive 1113	Accurate 1114	Timely 1114	Coverage 1114	Unobtrusive 1114	Resolution 1114	Scope 1114	Sensor Variety 1114
1.1	HypS Atk Acft	Reg	1	10 - 100	90	2	100	60	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	1 - 10	1	Reg	50	60	70	2
1.2	Fotofighter	Coun	1	0 - 1	95	3	50	90	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	0 - 1	1	Coun	50	70	90	2
1.3	Container Aircraft	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
1.4	L-T-A Airlifter	Coun	1	10 - 100	70	2	100	50	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
1.5	Supersonic Airlift	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
1.6	Stealth Airlifter	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
1.7	Glob Transport Ac	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
2.1	Strike UAV	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
2.2	Recce UAV	Coun	0	0 - 1	100	4	75	90	0	24	> 10,000	0	0	0	100	10 m	< 1 sec	40	1	0	0 - 1	0	Coun	75	70	95	4
2.3	UCAV	Coun	0	0 - 1	100	4	75	90	0	24	> 10,000	0	0	0	100	10 m	< 1 sec	40	1	0	0 - 1	0	Coun	75	70	95	4
2.4	PDS	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	0	N	100	0	0	1
2.5	UAV Mothership	Coun	1	0 - 1	70	2	100	60	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
2.6	Exfiltration Rocket	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
3.1	OMV	N	24	> 10,000	0	0	100	0	0	12	1 - 10	100	2	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
3.2	OCV	N	24	> 10,000	0	0	100	0	20	12	0 - 1	100	2	LEO	100	meter	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
3.3	SB	N	24	> 10,000	0	0	100	0	20	0	0 - 1	100	2	LEO	75	cm	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
4.1	Piloted SSTO TAV	Reg	1	1 - 10	95	3	100	60	50	0	1 - 10	90	2	Geo	100	meter	> 1 day	0	0	100	1 - 10	1	Reg	100	40	70	2
4.2	Uninhab AL TAV	Reg	1	1 - 10	95	3	100	60	50	0	1 - 10	90	2	Geo	100	meter	> 1 day	0	0	100	1 - 10	1	Reg	100	40	70	2
5.1	AYM	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
5.2	AAAM	N	24	0 - 1	90	5	100	90	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
5.3	Airborne HPMW	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
5.4	SHM	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	1 - 10	1	Coun	50	40	90	2
5.5	Attack Microbots	N	1	0 - 1	50	2	0	20	0	24	> 10,000	0	0	0	100	10 m	< 1 sec	20	1	0	0 - 1	1	N	20	20	70	2
5.6	Abn Holo Projecto	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
5.7	Hybrid HEL Sys	N	24	> 10,000	0	0	100	0	15	6	0 - 1	80	2	moon	0	cm	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
6.1	GLASS	Reg	1	1 - 10	95	3	100	80	50	0	1 - 10	90	2	Geo	100	meter	> 1 day	0	0	100	1 - 10	1	Reg	100	40	70	2
6.2	Space KEW	N	24	> 10,000	0	0	100	0	0	24	> 10000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
6.3	Space HPMW	N	24	> 10,000	0	0	100	0	0	24	> 10000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
6.4	Space HEL	Glob	0	0 - 1	75	2	65	70	100	0	0 - 1	100	2	moon	65	cm	> 1 day	0	0	100	0 - 1	0	Glob	65	70	50	2
6.5	Solar HEL	Glob	0	0 - 1	75	2	65	70	100	0	0 - 1	100	2	moon	65	cm	> 1 day	0	0	100	0 - 1	0	Glob	65	70	50	2
6.6	SEOW	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
6.7	AMS	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
7.1	SLT	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
7.2	PDA	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
7.3	Vis. Interactive Ctr	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
8.1	GIMS	Glob	0	0 - 1	100	6	20	100	100	0	0 - 1	100	4	moon	20	cm	< 1 sec	80	4	50	0 - 1	0	Glob	20	100	100	6
8.2	GSRT	Glob	0	0 - 1	100	4	65	80	100	0	0 - 1	100	4	moon	65	cm	< 1 sec	40	3	0	0 - 1	0	Glob	65	80	80	4
8.3	Sensor Microbots	N	1	0 - 1	50	6	0	20	0	24	> 10,000	0	0	0	100	10 m	< 1 sec	60	1	0	0 - 1	1	N	20	20	70	6
8.4	ML Sensor Sys	Coun	1	0 - 1	90	3	100	70	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	0 - 1	1	N	100	80	90	2
8.5	ADS	N	24	> 10,000	0	0	100	0	100	24	> 10,000	95	2	moon	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
9.1	MARS	N	24	> 10,000	0	0	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
9.2	WAMS	N	6	1 - 10	30	1	100	0	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	> 10,000	24	N	100	0	0	0
9.3	Sanctuary Base	N	0	0 - 1	100	6	20	90	0	24	> 10,000	0	0	0	100	10 m	> 1 day	0	0	100	0 - 1	0	N	20	90	100	6

Figure E-2. System Scoring—*Detect* Task

	System Name	Accurate 1121	Timely 1121	Traceable	Battlespace View	Timely 1122	Correlation 1122	Own Force Status	Other's Status	Environment	Decision Basis	Quality	Effective	Efficient	Security	Tailored (Sys-Hmn)	Interaction(Hmn-Hmn)	Capacity	Interoperable	BDA	Feedback	Doctrine	Tech/Ops Knowledge	Tech/Ops Skills	Critical/Creative T
1.1	HypS Atk Acft	90	JIT	80	10	JIT	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
1.2	Fotofighter	90	JIT	80	10	JIT	0	50	50	50	0	0	0	0	0	0	N	0	0	90	0	N	0	0	N
1.3	Container Aircraft	0	TL	0	50	JIT	25	75	60	75	50	50	50	50	70	50	VTC	2	4	0	24	N	0	0	N
1.4	L-T-A Airlifter	0	TL	0	5	JIT	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
1.5	Supersonic Airlift	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
1.6	Stealth Airlifter	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
1.7	Glob Transport Acft	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
2.1	Strike UAV	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
2.2	Recce UAV	95	IA	90	10	JIT	10	50	50	50	0	0	0	0	0	0	N	0	0	90	0.5	N	0	0	N
2.3	UCAV	95	IA	90	10	JIT	10	50	50	50	0	0	0	0	0	0	N	0	0	90	0	N	0	0	N
2.4	PDS	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
2.5	UAV Mothership	0	TL	0	10	JIT	10	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
2.6	Exfiltration Rocket	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
3.1	OMV	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
3.2	OCV	90	JIT	90	10	JIT	10	50	50	50	0	0	0	0	0	0	N	0	0	90	0	N	0	0	N
3.3	SB	90	JIT	90	10	JIT	10	50	50	50	0	0	0	0	0	0	N	0	0	90	0	N	0	0	N
4.1	Piloted SSTO TAV	80	JIT	80	10	JIT	0	50	50	50	0	0	0	0	0	0	N	0	0	80	1	N	0	0	N
4.2	Uninhab AL TAV	80	JIT	90	10	JIT	0	50	50	50	0	0	0	0	0	0	N	0	0	80	1	N	0	0	N
5.1	AYM	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
5.2	AAAM	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
5.3	Airborne HPMW	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
5.4	SHM	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
5.5	Attack Microbots	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
5.6	Abn Holo Projector	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
5.7	Hybrid HEL Sys	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	15	0	N	0	0	N
6.1	GLASS	80	JIT	80	10	JIT	0	50	50	50	0	0	0	0	0	0	N	0	0	80	1	N	0	0	N
6.2	Space KEW	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
6.3	Space HPMW	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
6.4	Space HEL	90	IA	90	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	60	0	N	0	0	N
6.5	Solar HEL	90	IA	90	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	60	0	N	0	0	N
6.6	SEOW	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
6.7	AMS	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
7.1	SLT	0	TL	0	20	JIT	20	50	50	50	25	0	20	20	0	100	Voice	0	7	0	24	Comp	20	50	N
7.2	PDA	0	TL	0	50	IA	50	70	70	60	50	0	50	50	95	100	VTC	2	7	50	0	Comp	70	90	Comp
7.3	Vis. Interactive Ctr	0	TL	0	100	IA	50	95	90	90	90	80	100	100	95	100	VR	0	7	0	24	Eval	80	95	Synth
8.1	GIMS	99	IA	90	100	IA	100	100	100	100	100	100	100	100	95	100	VR	20	7	100	0	Eval	80	95	Synth
8.2	GSRT	95	IA	90	70	IA	70	90	80	70	80	70	70	80	90	50	VR	15	7	95	0	N	0	0	N
8.3	Sensor Microbots	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	50	1	N	0	0	N
8.4	ML Sensor Sys	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	50	1	N	0	0	N
8.5	ADS	95	IA	100	0	JIT	0	50	50	50	0	0	0	0	0	0	N	0	0	100	24	N	0	0	N
9.1	MARS	0	TL	0	0	TL	0	50	50	50	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
9.2	WAMS	0	TL	0	0	JIT	0	50	50	80	0	0	0	0	0	0	N	0	0	0	24	N	0	0	N
9.3	Sanctuary Base	100	JIT	100	100	JIT	50	50	50	90	90	80	100	100	95	100	VR	5	7	90	0	N	0	0	N

Figure E-3. System Scoring—*Understand/Direct* Tasks

	System Name	Payload Weight 1211	Payload Volume 1211	Range 1211	Responsive 1211	Multirole 1211	Payload Weight 1212	Payload Volume 1212	Responsive 1212	Reusable 1212	Specific Impulse	Perf.A, Surf-Space	Perf.B, Space-Space	Payload Weight 1213	Payload Volume 1213	Range 1213	Forward Basing Reqt	Available 1221	Footprint 1222	Supportable 1221	Pipeline 1222	Responsive 1213	Multirole 1213	Timely 1231	Accurate 1231	Transfer 1231	Multicommodity1231	Transfer Rate 1231	Timely 1232	Accurate 1232	Transfer 1232	Reusable 1232	Transfer Rate 1232	Timely 1233	Accurate 1233	Transfer 1233
1.1	HypS Atk Acft	50	20	10	0.5	1	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	80	S	80	Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
1.2	Fotofighter	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	80	M	70	Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
1.3	Container Aircraft	0	0	0	10	0	0	0	30	0	0	0	0	200	50	10	Bare Base	80	M	80	Depot	2	3	24	80	0	0	60	7	< 100%	0	0	W	2	FOB	100
1.4	L-T-A Airlifter	250	100	12.5	7	3	0	0	30	0	0	0	0	250	100	12.5	Bare Base	85	M	80	Depot	7	3	12	100	97	4	60	7	< 100%	0	0	W	7	FOB	100
1.5	Supersonic Airlift	0	0	0	10	0	0	0	30	0	0	0	0	50	50	0	Full Base	75	M	80	Depot	0.5	3	24	80	0	0	60	7	< 100%	0	0	W	0.5	FOB	100
1.6	Stealth Airlifter	0	0	0	10	0	0	0	30	0	0	0	0	10	12.5	5	N	80	S	70	Depot	1	2	24	80	0	0	60	7	< 100%	0	0	W	1	Unit	100
1.7	Glob Transport Ac	0	0	0	10	0	0	0	30	0	0	0	0	250	75	12	Full Base	90	M	80	Depot	2	3	3	100	97	1	5	7	< 100%	0	0	W	1	Unit	100
2.1	Strike UAV	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	90	S	90	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
2.2	Recce UAV	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	90	S	90	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
2.3	UCAV	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	90	S	90	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
2.4	PDS	0	0	0	10	0	0	0	30	0	0	0	0	5	12.5	0	N	90	S	95	Mx sqdn	0.5	2	24	80	0	0	60	7	< 100%	0	0	W	0.5	Sys	95
2.5	UAV Mothership	50	25	5	0.5	1	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	80	M	90	Depot	10	0	1	99	97	5	1	7	< 100%	0	0	W	10	Thea	0
2.6	Exfiltration Rocket	0	0	0	10	0	0	0	30	0	0	0	0	1	1	0.5	N	100	M	25	Mx sqdn	0	1	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
3.1	OMV	0	0	0	10	0	20	15	2	100	1,000	0	5	0	0	0	Huge/N.A.	80	M	50	Depot	10	0	24	80	0	0	60	2	1	100	100	H	10	Thea	0
3.2	OCV	0	0	0	10	0	20	15	2	100	1,000	0	5	0	0	0	Huge/N.A.	80	M	50	Depot	10	0	24	80	0	0	60	2	1	100	100	H	10	Thea	0
3.3	SB	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	50	Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
4.1	Piloted SSTO TAV	0	0	0	10	0	5	2	0.5	100	1,000	45	0	0	0	0	Huge/N.A.	80	S	80	Depot	10	0	24	80	0	0	60	0.5	1	100	100	H	10	Thea	0
4.2	Uninhab AL TAV	0	0	0	10	0	3	0.65	0.5	100	1,000	45	0	0	0	0	Huge/N.A.	70	S	80	Depot	10	0	24	80	0	0	60	0.5	1	100	100	H	10	Thea	0
5.1	AYM	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	S	95	5 vans	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
5.2	AAAM	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	S	95	5 vans	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
5.3	Airborne HPMW	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	S	95	5 vans	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
5.4	SHM	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	S	95	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
5.5	Attack Microbots	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	N	0	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
5.6	Abn Holo Projecto	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	90	S	90	5 vans	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
5.7	Hybrid HEL Sys	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	70	10*Depot	10	0	24	80	0	0	60	0.1	1	95	100	M	10	Thea	0
6.1	GLASS	0	0	0	10	0	5	2	0.5	100	1,000	45	0	0	0	0	Huge/N.A.	100	M	70	10*Depot	10	0	24	80	0	0	60	0.5	1	100	100	H	10	Thea	0
6.2	Space KEW	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	50	Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
6.3	Space HPMW	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	50	Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
6.4	Space HEL	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	50	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
6.5	Solar HEL	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	50	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
6.6	SEOW	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	M	50	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
6.7	AMS	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	S	60	Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
7.1	SLT	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	N	60	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
7.2	PDA	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	N	40	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
7.3	Vis. Interactive Ctr	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	N	95	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
8.1	GIMS	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	50	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
8.2	GSRT	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	50	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
8.3	Sensor Microbots	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	N	0	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
8.4	ML Sensor Sys	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	80	S	90	5 vans	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
8.5	ADS	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	M	70	Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
9.1	MARS	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	N	##	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
9.2	WAMS	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	95	L	90	Mx sqdn	10	0	24	80	0	0	60	7	< 100%	0	0	W	10	Thea	0
9.3	Sanctuary Base	0	0	0	10	0	0	0	30	0	0	0	0	0	0	0	Huge/N.A.	100	N	##	10*Depot	10	0	24	80	0	0	60	7	< 100%	0	0	W	0	Sys	100

Figure E-4. System Scoring—*Deploy/Maintain/Replenish* Tasks

	System Name	Detectable 1311	Countermeasures 1311	Vulnerable 1311	Recoverable 1311	Detectable 1312	Countermeasures 1312	Vulnerable 1312	Recoverable 1312	Detectable 1313	Countermeasures 1313	Vulnerable 1313	Recoverable 1313	Detectable 1314	Countermeasures 1314	Vulnerable 1314	Recoverable 1314
1.1	HypS Atk Acft	0.8	0.1	0.5	24	1	1	1	24	1	0	1	24	1	1	1	24
1.2	Fotofighter	0.5	0.1	0.5	24	1	1	1	24	1	0	1	24	1	1	1	24
1.3	Container Aircraft	1	1	1	24	1	1	1	24	0.8	1	0.6	3	0.9	0.5	0.5	24
1.4	L-T-A Airlifter	1	1	0.6	24	1	1	1	24	1	0	1	24	1	1	1	24
1.5	Supersonic Airlift	0.9	0.5	0.8	24	1	1	1	24	1	0	1	24	1	1	1	24
1.6	Stealth Airlifter	0.1	0.3	0.5	24	1	1	1	24	1	0	1	24	1	1	1	24
1.7	Glob Transport Ac(	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
2.1	Strike UAV	0.3	0.3	0.5	12	1	1	1	24	1	0	1	24	1	1	1	24
2.2	Recce UAV	0.5	0.4	0.5	12	1	1	1	24	1	0	1	24	1	1	1	24
2.3	UCAV	0.5	0.4	0.5	12	1	1	1	24	1	0	1	24	1	1	1	24
2.4	PDS	0.7	0.7	0.5	12	1	1	1	24	1	0	1	24	1	1	1	24
2.5	UAV Mothership	1	0.9	0.6	24	1	1	1	24	1	0	1	24	1	1	1	24
2.6	Exfiltration Rocket	1	0.8	1	24	1	1	1	24	1	0	1	24	0.2	1	1	24
3.1	OMV	1	1	1	24	1	0.7	0.9	24	1	0	1	24	1	1	1	24
3.2	OCV	1	1	1	24	1	0.4	0.9	24	1	0	1	24	1	1	1	24
3.3	SB	1	1	1	24	0.7	0.4	0.5	24	1	0	1	24	1	1	1	24
4.1	Piloted SSTO TAV	1	1	1	24	1	0.4	0.9	24	1	0	1	24	1	1	1	24
4.2	Uninhab AL TAV	1	1	1	24	1	0.4	0.9	24	1	0	1	24	1	1	1	24
5.1	AYM	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
5.2	AAAM	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
5.3	Airborne HPMW	1	0.1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
5.4	SHM	0.6	0.2	1	24	1	1	1	24	1	0	1	24	1	1	1	24
5.5	Attack Microbots	0.1	0.1	0.1	24	1	1	1	24	0.1	0	0.1	24	0.1	0.1	0.1	24
5.6	Abn Holo Projecto(	0.5	0.5	1	24	1	1	1	24	1	0	1	24	1	1	1	24
5.7	Hybrid HEL Sys	1	1	1	24	1	0.4	0.1	12	1	0	1	24	1	0.5	1	24
6.1	GLASS	1	1	1	24	1	0.4	0.1	6	1	0	1	24	1	0.5	0.3	12
6.2	Space KEW	1	1	1	24	1	0.7	0.1	12	1	0	1	24	1	1	1	24
6.3	Space HPMW	1	1	1	24	1	0.7	0.1	12	1	0	1	24	1	1	1	24
6.4	Space HEL	1	1	1	24	1	0.4	0.1	12	1	0	1	24	1	1	1	24
6.5	Solar HEL	1	1	1	24	1	0.4	0.1	12	1	0	1	24	1	1	1	24
6.6	SEOW	1	1	1	24	1	0.7	0.9	24	1	0	1	24	1	1	1	24
6.7	AMS	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
7.1	SLT	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
7.2	PDA	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
7.3	Vis. Interactive Ctr	1	1	1	24	1	1	1	24	1	0	1	24	1	0.5	0.3	6
8.1	GIMS	0.1	0.1	0.1	6	1	0.7	0.1	6	0.1	5	0.1	1	0.2	0.1	0.1	6
8.2	GSRT	1	1	1	24	1	0.7	0.1	6	0.5	3	0.3	3	1	1	1	24
8.3	Sensor Microbots	0.1	0.1	0.1	24	1	1	1	24	0.1	0	0.1	24	0.1	0.1	0.1	24
8.4	ML Sensor Sys	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
8.5	ADS	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
9.1	MARS	1	1	1	24	1	1	1	24	1	0	1	24	1	1	1	24
9.2	WAMS	0.8	0.5	1	24	1	1	1	24	1	0	1	24	1	1	1	24
9.3	Sanctuary Base	1	1	1	24	1	1	1	24	0.8	1	0.6	3	0.5	0.01	0.2	6

Figure E-5. System Scoring—*Survive* Task

	System Name	Precise 1321	Timely 1321	Range 1321	Desired Lethal 1321	Reusable P-form 1321	WeaponCapacity 1321	Multirole 1321	Unobtrusive 1321	Scope 1321	Timely 1322	Desired Lethal 1322	Reusable P-form 1322	WeaponCapacity 1322	Unobtrusive 1322	Scope 1322	Range 1322	Multirole 1322	Precise 1323	Timely 1323	Desired Lethal 1323	Multirole 1323	Unobtrusive 1323	Precise 1324	Timely 1324	EngagementEnv 1324	Desired Lethal 1324	Reusable P-form 1324	WeaponCapacity 1324	Multirole 1324	Unobtrusive 1324	Scope 1324
1.1	HypS Atk Acft	1 - 10	1	0	0.2	100	10	1	100	80	24	0	0	0	100	0	0	0	FR	60	0	0	100	0 - 1	1	1	0.8	100	10	2	100	80
1.2	Fotofighter	0 - 1	1	0	0.9	1,000	100	3	80	80	24	0	0	0	100	0	0	0	FR	60	0	0	100	0 - 1	1	0	0.5	1,000	100	3	80	70
1.3	Container Aircraft	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
1.4	L-T-A Airlifter	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
1.5	Supersonic Airlift	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
1.6	Stealth Airlifter	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
1.7	Glob Transport Acft	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
2.1	Strike UAV	1 - 10	1	0	0.6	100	10	1	30	80	24	0	0	0	100	0	0	0	FR	60	0	0	100	0 - 1	1	0.5	0.8	100	10	2	30	80
2.2	Recce UAV	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
2.3	UCAV	1 - 10	1	0	0.6	100	10	2	100	80	24	0	0	0	100	0	0	0	ED	0	0.8	1	100	0 - 1	1	0.5	0.8	100	10	2	100	80
2.4	PDS	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
2.5	UAV Mothership	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
2.6	Exfiltration Rocket	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
3.1	OMV	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
3.2	OCV	> 1,000	24	0	0	0	0	0	100	0	0	0.8	100	1,000	100	100	5	2	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
3.3	SB	> 1,000	24	0	0	0	0	0	100	0	0	0.8	10	10	100	100	5	2	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
4.1	Piloted SSTO TAV	> 1,000	24	0	0	0	0	0	100	0	1	0.95	100	10	100	100	12.5	1	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
4.2	Uninhab AL TAV	> 1,000	24	0	0	0	0	0	100	0	1	0.95	100	10	100	100	12.5	1	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
5.1	AYM	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	0 - 1	1	0	0.9	1	1	2	20	100
5.2	AAAM	1 - 10	0	0	0.9	1	1	1	100	100	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
5.3	Airborne HPMW	10 - 100	1	0	0.7	1,000	100	3	100	100	24	0	0	0	100	0	0	0	CD	0	0.7	2	100	10 - 100	1	0	0.5	1,000	100	3	100	90
5.4	SHM	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	0 - 1	1	1.5	0.9	1	1	1	40	100
5.5	Attack Microbots	0 - 1	1	0	0.2	1	1	2	10	50	24	0	0	0	100	0	0	0	ED	0	0.9	3	10	0 - 1	1	0	0.5	1	1	2	10	70
5.6	Abn Holo Projector	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	0 - 1	1	0	0.5	1,000	100	1	50	75
5.7	Hybrid HEL Sys	0 - 1	0	12	0.8	1,000	1,000	3	100	75	0	0.95	1,000	1,000	100	100	25	3	FR	60	0	0	100	0 - 1	0	12	0.7	1,000	1,000	3	100	50
6.1	GLASS	0 - 1	0	12	0.9	1,000	1,000	3	80	100	0	0.95	1,000	1,000	80	100	25	3	FR	60	0	0	100	0 - 1	0	12	0.95	1,000	1,000	3	80	100
6.2	Space KEW	0 - 1	0	12	0.9	1,000	1,000	1	50	100	0	0.95	1,000	1,000	50	100	25	1	FR	60	0	0	100	0 - 1	0	12	0.95	1,000	1,000	1	50	100
6.3	Space HPMW	10 - 100	0	12	0.6	1,000	1,000	3	100	90	0	0.95	1,000	1,000	100	100	25	3	CD	0	0.5	2	100	100 - 1,000	0	12	0.4	1,000	1,000	3	100	80
6.4	Space HEL	0 - 1	0	12	0.8	1,000	1,000	3	100	75	0	0.95	1,000	1,000	100	100	25	3	FR	60	0	0	100	0 - 1	0	12	0.7	1,000	1,000	3	100	50
6.5	Solar HEL	0 - 1	0	12	0.8	1,000	100	3	100	75	0	0.95	1,000	100	100	100	25	3	FR	60	0	0	100	0 - 1	0	12	0.7	1,000	100	3	100	50
6.6	SEOW	> 1,000	24	0	0	0	0	0	100	0	0	0.4	1,000	1,000	100	100	25	1	FR	60	0	0	100	100 - 1,000	0	12	0.2	1,000	100	1	100	50
6.7	AMS	> 1,000	24	0	0	0	0	0	100	0	24	0.1	1	10	100	100	25	1	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
7.1	SLT	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
7.2	PDA	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
7.3	Vis. Interactive Ctr	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
8.1	GIMS	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
8.2	GSRT	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
8.3	Sensor Microbots	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
8.4	ML Sensor Sys	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
8.5	ADS	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
9.1	MARS	> 1,000	24	0	0	0	0	0	100	0	24	0	0	0	100	0	0	0	FR	60	0	0	100	> 1,000	24	0	0	0	0	0	100	0
9.2	WAMS	> 1,000	24	0	0	0	0	0	100	0	1	0.1	1,000	1	50	50	1.2	2	FR	60	0	0	100	> 1,000	6	0	0.4	1,000	0	2	50	100
9.3	Sanctuary Base	0 - 1	0	0.5	90	1,000	1,000	2	100	100	24	0	0	0	100	0	0	0	FR	60	0	0	100	0 - 1	0	0.5	80	1,000	1,000	2	100	100

Figure E-6. System Scoring—*Engage* Task

System Name	Gulliver's	Zaibatsu	Khan	Digital	2015	Halfs
1.1 Hypersonic Attack Aircraft	24.3	21.9	24.3	20.3	22.9	24.3
1.2 Fotofighter	24.3	22.5	24.5	21.2	23.6	24.3
1.3 Container Aircraft	16.0	14.9	15.8	14.8	14.2	15.9
1.4 Lighter-than-Air Airlifter	18.2	14.2	17.8	13.7	15.7	18.2
1.5 Supersonic Airlifter	8.8	5.9	8.5	5.6	7.6	8.8
1.6 Stealth Airlifter	10.5	7.2	10.3	6.8	9.5	10.5
1.7 Global Transport Aircraft	13.1	9.1	12.7	8.9	11.5	13.1
2.1 Strike UAV	14.9	10.7	14.9	10.4	15.0	14.9
2.2 Reconnaissance UAV	26.9	30.1	26.7	28.8	25.1	26.9
2.3 Uninhabited Combat Air Vehicle	34.5	36.0	34.5	35.4	33.5	34.5
2.4 Precision Delivery System	16.4	12.0	16.0	11.5	14.6	16.4
2.5 UAV Mothership	14.6	12.9	14.3	12.8	13.4	14.6
2.6 Exfiltration Rocket	8.9	6.3	8.7	6.0	7.8	8.9
3.1 Orbital Maneuvering Vehicle	8.4	9.2	8.2	9.3	8.4	8.4
3.2 Orbital Combat Vehicle	20.0	24.0	19.9	23.5	20.1	20.0
3.3 Satellite Bodyguards	18.6	22.4	18.5	21.4	19.0	18.6
4.1 Piloted SSTO Transatmospheric Vehicle	25.5	28.5	25.4	28.0	25.5	25.5
4.2 Uninhabited Air-Launched TAV	25.3	28.4	25.1	27.8	25.2	25.3
5.1 Adjustable Yield Munition	12.9	9.5	12.8	9.3	12.3	12.9
5.2 Advanced Air-to-Air Missile	12.9	10.4	12.7	10.3	13.2	12.9
5.3 Airborne High-Power Microwave Weapon	16.8	13.6	16.8	14.3	17.7	16.8
5.4 Standoff Hypersonic Missile	15.1	11.5	15.1	11.2	14.3	15.1
5.5 Attack Microbots	26.4	25.6	26.7	26.8	28.4	26.4
5.6 Airborne Holographic Projector	11.9	9.0	11.8	8.8	11.5	11.9
5.7 Hybrid High-Energy Laser System	19.8	18.5	20.0	18.7	21.9	19.8
6.1 Global Area Strike System	35.3	34.7	35.5	33.8	36.1	35.3
6.2 Space-Based Kinetic Energy Weapon	15.8	12.2	16.0	12.2	17.4	15.8
6.3 Space-Based High-Power Microwave Weapon	14.3	12.6	14.6	13.4	16.4	14.3
6.4 Space-Based High-Energy Laser	28.4	28.4	28.6	26.8	29.3	28.4
6.5 Solar-Powered High-Energy Laser System	28.2	28.3	28.4	26.6	29.1	28.2
6.6 Solar Energy Optical Weapon	7.8	6.6	7.8	6.7	8.3	7.8
6.7 Asteroid Mitigation System	6.0	5.3	5.9	5.3	6.1	6.0
7.1 Spoken Language Translator	11.6	11.6	11.4	11.6	10.7	11.6
7.2 Personal Digital Assistant	17.3	18.3	17.1	18.6	15.9	17.4
7.3 Virtual Interaction Center	23.2	24.2	23.0	23.9	21.3	23.2
8.1 Global Information Management System	47.7	55.5	47.8	54.2	47.0	47.7
8.2 Global Surveillance, Recon, and Targeting System	35.9	43.8	35.9	42.6	34.2	35.9
8.3 Sensor Microbots	20.9	21.5	20.9	21.9	21.8	20.9
8.4 Multiband Laser Sensor System	13.0	11.4	12.8	11.3	12.4	13.0
8.5 Asteroid Detection System	15.0	17.8	14.8	16.2	14.0	15.0
9.1 Mobile Asset Repair Station	7.7	6.4	7.4	6.4	7.4	7.7
9.2 Weather Analysis and Modification System	13.5	11.9	13.4	11.9	13.4	13.5
9.3 Sanctuary Base	47.3	44.2	47.3	42.3	44.6	47.3

Figure E-7. Final System Values by Future—AU Team Weights

System Name	Gulliver's	Zaibatsu	Khan	Digital	2015	Halfs
1.1 Hypersonic Attack Aircraft	28.9	24.4	23.9	20.3	28.9	21.1
1.2 Fotofighter	27.3	23.2	24.5	23.5	31.1	21.9
1.3 Container Aircraft	15.2	8.7	13.9	10.5	13.1	12.5
1.4 Lighter-than-Air Airlifter	19.0	13.4	16.6	7.8	15.1	12.5
1.5 Supersonic Airlifter	9.8	4.2	8.3	1.9	6.0	5.7
1.6 Stealth Airlifter	12.5	5.4	10.2	3.6	8.1	7.6
1.7 Global Transport Aircraft	14.3	5.4	13.1	2.1	9.8	9.0
2.1 Strike UAV	16.9	7.6	13.8	7.9	17.4	14.0
2.2 Reconnaissance UAV	26.8	32.8	31.2	25.2	24.5	23.5
2.3 Uninhabited Combat Air Vehicle	35.9	42.6	36.8	35.0	37.3	33.8
2.4 Precision Delivery System	17.7	7.8	17.6	3.5	10.9	11.4
2.5 UAV Mothership	13.4	9.3	14.6	6.9	12.9	11.2
2.6 Exfiltration Rocket	10.7	5.1	9.2	2.6	5.8	6.4
3.1 Orbital Maneuvering Vehicle	5.3	6.9	8.3	5.0	4.9	7.6
3.2 Orbital Combat Vehicle	14.9	18.6	20.0	18.4	16.0	17.8
3.3 Satellite Bodyguards	14.6	18.0	19.6	17.6	14.6	15.9
4.1 Piloted SSTO Transatmospheric Vehicle	19.7	24.6	28.1	21.5	20.1	22.0
4.2 Uninhabited Air-Launched TAV	19.6	24.8	27.9	21.7	20.2	21.9
5.1 Adjustable Yield Munition	14.5	5.2	12.0	4.4	10.3	11.0
5.2 Advanced Air-to-Air Missile	10.8	6.1	15.5	5.6	12.8	11.5
5.3 Airborne High Power Microwave Weapon	17.4	11.6	17.6	11.5	18.5	18.1
5.4 Standoff Hypersonic Missile	18.3	9.0	16.2	6.0	12.9	12.6
5.5 Attack Microbots	28.4	34.6	29.9	30.0	30.0	32.9
5.6 Airborne Holographic Projector	13.2	4.6	11.7	4.0	9.3	10.3
5.7 Hybrid High-Energy Laser System	15.9	15.0	18.3	15.9	21.6	19.8
6.1 Global Area Strike System	32.3	32.9	34.4	31.3	38.6	32.6
6.2 Space-Based Kinetic Energy Weapon	15.9	9.8	14.5	10.6	19.9	15.5
6.3 Space-Based High-Power Microwave Weapon	12.7	11.0	15.2	11.2	15.9	15.8
6.4 Space-Based High-Energy Laser	28.0	31.6	30.3	27.2	31.5	26.1
6.5 Solar-Powered High-Energy Laser System	27.8	31.4	30.2	27.1	31.2	25.9
6.6 Solar Energy Optical Weapon	7.3	3.6	7.9	3.3	5.6	7.0
6.7 Asteroid Mitigation System	4.8	1.5	7.6	0.9	2.9	5.0
7.1 Spoken Language Translator	9.7	4.2	11.3	7.4	8.2	9.2
7.2 Personal Digital Assistant	14.2	6.4	15.7	16.6	13.7	14.5
7.3 Virtual Interaction Center	20.4	8.4	22.1	20.5	20.1	20.6
8.1 Global Information Management System	45.6	52.8	50.8	60.3	46.9	49.4
8.2 Global Surveillance, Recon, and Targeting System	31.2	45.9	37.5	41.8	32.5	33.2
8.3 Sensor Microbots	21.0	26.1	25.6	22.5	19.5	23.6
8.4 Multiband Laser Sensor System	11.5	8.2	17.1	6.6	9.0	10.1
8.5 Asteroid Detection System	15.3	15.9	16.3	14.0	13.6	12.9
9.1 Mobile Asset Repair Station	6.6	1.5	9.6	0.8	3.8	6.2
9.2 Weather Analysis and Modification System	12.3	6.6	13.5	6.6	10.7	11.5
9.3 Sanctuary Base	48.5	34.4	46.7	39.5	52.5	41.8

Figure E-8. Final System Values by Future—Alternate Futures Weights

Appendix F

Technology Scores

This appendix gives the numerical data from the technology assessment. Table 5 shows the raw technology scores for each system. These scores were then multiplied by each system's value for a given alternate future and set of Value Model weights. The weighted technology score was computed by adding all (or top 11) of the system's weighted scores for a given technology area. Finally, the results were normalized to a 100-point scale and are presented in table 6 through table 9.

Table 5

Technology Scores by System

SYSTEM	MCTL 1.0	MCTL 2.1	MCTL 2.2.1	MCTL 2.2.5	MCTL 2.6	MCTL 4.1.1	MCTL 4.1.2	MCTL 4.1.3	MCTL 4.1.4
1.0 AIR VEHICLES (PILOTED)									
1.1 Hypersonic Attack Aircraft	20	0	0	0	0	10	0	0	0
1.2 Fotofighter	10	0	0	0	20	10	0	0	0
1.3 Container Aircraft	10	0	0	0	0	0	0	0	0
1.4 Lighter-than-Air Airlifter	40	0	0	0	0	10	0	0	0
1.5 Supersonic Airlifter	30	0	0	0	0	10	0	0	0
1.6 Stealth Airlifter	30	0	0	0	0	0	0	0	0
1.7 Global Transport Aircraft	40	0	0	0	0	0	0	0	0
2.0 AIR VEHICLES (UNINHABITED)									
2.1 Strike UAV	5	0	0	0	0	0	0	0	5
2.2 Reconnaissance UAV	10	0	0	0	0	0	0	10	10
2.3 Uninhabited Combat Air Vehicle	10	0	0	0	0	0	0	5	10
2.4 Precision Delivery System	20	0	0	0	10	0	0	0	0
2.5 UAV Mothership	5	0	0	20	0	0	0	0	0
2.6 Exfiltration Rocket	25	0	0	0	0	0	0	0	0
3.0 SPACE VEHICLES									
3.1 Orbital Maneuvering Vehicle	0	0	0	20	10	5	0	0	0
3.2 Orbital Combat Vehicle	0	0	0	20	10	5	0	0	0
3.3 Satellite Bodyguards	0	0	0	0	0	10	0	5	0
4.0 AIR AND SPACE VEHICLES									
4.1 Piloted SSTO Transatmospheric Vehicle	20	0	0	0	0	10	0	0	0
4.2 Uninhabited Air-Launched Transatmospheric Vehicle	10	0	0	10	0	10	0	0	0
5.0 AIR AND GROUND-BASED WEAPONS									
5.1 Adjustable Yield Munition	0	0	0	0	0	0	0	0	0
5.2 Advanced Air-to-Air Missile	0	0	0	0	20	10	0	0	0
5.3 Airborne High-Power Microwave Weapon	10	0	0	0	0	0	0	0	0
5.4 Standoff Hypersonic Missile	10	0	0	0	0	0	0	0	0
5.5 Attack Microbots	0	0	0	10	35	5	0	0	0
5.6 Airborne Holographic Projector	0	0	0	0	0	10	0	0	70
5.7 Hybrid High-Energy Laser	0	0	0	0	0	0	0	0	0
6.0 SPACE-BASED WEAPONS									
6.1 Global Area Strike System	10	0	0	0	5	10	0	0	0
6.2 Space-Based Kinetic Energy Weapon	15	0	0	0	15	10	0	0	0
6.3 Space-Based High-Power Microwave Weapon	10	0	0	0	0	10	0	0	0
6.4 Space-Based High-Energy Laser System	0	0	0	0	0	4	0	8	8
6.5 Solar-Powered High-Energy Laser System	0	0	0	0	0	3	0	6	6
6.6 Solar Energy Optical Weapon	0	0	0	10	0	0	0	0	0
6.7 Asteroid Mitigation System	0	0	0	0	0	0	0	0	0
7.0 INDIVIDUAL INFORMATION SYSTEMS									
7.1 Spoken Language Translator	0	0	0	0	0	20	0	0	0
7.2 Personal Digital Assistant	0	0	0	0	5	10	0	10	0
7.3 Virtual Interaction Center	0	0	0	0	0	20	50	0	20
8.0 GLOBAL INFORMATION SYSTEMS									
8.1 Global Information Management System	0	0	0	0	5	5	7	4	4
8.2 Global Surveillance, Reconnaissance, and Targeting Sys	0	0	0	0	10	6	0	7	7
8.3 Sensor Microbots	0	0	0	5	35	5	0	0	0
8.4 Multiband Laser Sensor System	0	0	0	0	0	10	0	0	5
8.5 Asteroid Detection System	0	0	0	0	0	10	0	0	15
9.0 MISCELLANEOUS SYSTEMS									
9.1 Mobile Asset Repair Station	30	30	15	15	10	0	0	0	0
9.2 Weather Analysis and Modification System	0	0	0	0	5	25	0	0	0
9.3 Sanctuary Base	10	5	0	15	15	5	4	0	3

Table 5 (Continued)

SYSTEM	MCTL 4.1.6	MCTL 4.2.4	MCTL 4.2.5	MCTL 4.2.9	MCTL 4.3	MCTL 5.1	MCTL 5.3	MCTL 5.4	MCTL 5.5
1.0 AIR VEHICLES (PILOTED)									
1.1 Hypersonic Attack Aircraft	0	0	0	0	0	0	0	0	0
1.2 Fotofighter	0	0	5	5	10	0	0	0	0
1.3 Container Aircraft	0	0	0	0	0	0	0	15	0
1.4 Lighter-than-Air Airlifter	0	0	0	0	0	0	0	0	0
1.5 Supersonic Airlifter	0	0	0	0	0	0	0	0	0
1.6 Stealth Airlifter	0	0	0	0	0	0	0	0	0
1.7 Global Transport Aircraft	0	0	0	0	0	0	0	0	0
2.0 AIR VEHICLES (UNINHABITED)									
2.1 Strike UAV	0	0	5	0	0	0	0	20	15
2.2 Reconnaissance UAV	0	0	20	0	0	10	0	0	0
2.3 Uninhabited Combat Air Vehicle	0	0	10	10	0	5	0	0	5
2.4 Precision Delivery System	0	0	0	0	0	0	0	0	0
2.5 UAV Mothership	0	0	0	0	0	0	0	0	0
2.6 Exfiltration Rocket	0	0	0	0	0	0	0	0	0
3.0 SPACE VEHICLES									
3.1 Orbital Maneuvering Vehicle	0	0	0	20	0	0	0	0	0
3.2 Orbital Combat Vehicle	0	0	0	20	0	0	0	0	0
3.3 Satellite Bodyguards	0	0	20	0	0	0	0	0	0
4.0 AIR AND SPACE VEHICLES									
4.1 Piloted SSTO Transatmospheric Vehicle	0	0	0	0	0	0	0	0	0
4.2 Uninhabited Air-Launched Transatmospheric Vehicle	0	0	10	10	0	0	0	0	0
5.0 AIR AND GROUND-BASED WEAPONS									
5.1 Adjustable Yield Munition	0	0	0	0	0	0	0	0	0
5.2 Advanced Air-to-Air Missile	0	0	20	0	0	0	0	0	0
5.3 Airborne High Power Microwave Weapon	0	0	0	0	0	0	0	0	0
5.4 Standoff Hypersonic Missile	0	0	0	0	0	10	0	0	0
5.5 Attack Microbots	0	0	5	5	0	5	0	5	0
5.6 Airborne Holographic Projector	0	0	0	0	0	0	0	0	0
5.7 Hybrid High-Energy Laser	0	0	0	0	0	0	0	0	0
6.0 SPACE-BASED WEAPONS									
6.1 Global Area Strike System	0	0	0	0	0	5	0	0	0
6.2 Space-Based Kinetic Energy Weapon	0	0	0	0	0	15	0	0	0
6.3 Space-Based High-Power Microwave Weapon	0	0	0	0	0	0	0	0	0
6.4 Space-Based High-Energy Laser System	0	10	10	0	0	0	0	0	0
6.5 Solar-Powered High-Energy Laser System	0	7	8	0	0	0	0	0	0
6.6 Solar Energy Optical Weapon	0	0	0	0	0	0	0	0	0
6.7 Asteroid Mitigation System	0	0	0	0	0	0	0	0	0
7.0 INDIVIDUAL INFORMATION SYSTEMS									
7.1 Spoken Language Translator	20	0	0	60	0	0	0	0	0
7.2 Personal Digital Assistant	5	0	0	10	0	10	25	0	5
7.3 Virtual Interaction Center	0	10	0	0	0	0	0	0	0
8.0 GLOBAL INFORMATION SYSTEMS									
8.1 Global Information Management System	0	5	15	15	0	8	4	5	8
8.2 Global Surveillance, Reconnaissance, and Targeting System	0	5	15	0	0	8	4	5	8
8.3 Sensor Microbots	0	0	5	5	0	5	0	5	0
8.4 Multiband Laser Sensor System	0	0	0	0	0	0	0	0	0
8.5 Asteroid Detection System	0	0	15	0	0	0	0	0	0
9.0 MISCELLANEOUS SYSTEMS									
9.1 Mobile Asset Repair Station	0	0	0	0	0	0	0	0	0
9.2 Weather Analysis and Modification System	0	0	10	20	10	0	0	0	0
9.3 Sanctuary Base	0	3	0	5	0	0	0	0	0

Table 5 (Continued)

SYSTEM	MCTL 6.1	MCTL 6.2	MCTL 6.4	MCTL 6.6	MCTL 6.7	MCTL 6.8	MCTL 6.9	MCTL 7.3	MCTL 9.1
1.0 AIR VEHICLES (PILOTED)									
1.1 Hypersonic Attack Aircraft	0	0	0	0	0	0	0	0	0
1.2 Fotofighter	0	5	0	0	0	5	0	0	0
1.3 Container Aircraft	0	0	0	0	0	0	0	25	0
1.4 Lighter-than-Air Airlifter	0	0	0	0	0	0	0	10	0
1.5 Supersonic Airlifter	0	0	0	0	0	0	0	0	30
1.6 Stealth Airlifter	0	0	0	0	0	0	0	0	35
1.7 Global Transport Aircraft	0	0	0	0	0	0	0	0	30
2.0 AIR VEHICLES (UNINHABITED)									
2.1 Strike UAV	0	0	0	0	0	0	0	0	0
2.2 Reconnaissance UAV	0	10	0	0	0	10	10	0	0
2.3 Uninhabited Combat Air Vehicle	0	5	10	0	0	5	5	0	0
2.4 Precision Delivery System	0	0	0	0	0	0	0	70	0
2.5 UAV Mothership	0	0	0	0	0	0	0	0	0
2.6 Exfiltration Rocket	0	0	0	0	0	0	0	15	0
3.0 SPACE VEHICLES									
3.1 Orbital Maneuvering Vehicle	0	0	0	0	0	0	0	0	0
3.2 Orbital Combat Vehicle	0	0	0	0	0	0	0	0	0
3.3 Satellite Bodyguards	0	0	0	0	0	0	0	0	0
4.0 AIR AND SPACE VEHICLES									
4.1 Piloted SSTO Transatmospheric Vehicle	0	0	0	0	0	0	0	0	0
4.2 Uninhabited Air-Launched Transatmospheric Vehicle	0	0	0	0	0	0	0	10	0
5.0 AIR AND GROUND-BASED WEAPONS									
5.1 Adjustable Yield Munition	0	0	0	0	0	0	0	0	0
5.2 Advanced Air-to-Air Missile	5	10	5	5	0	10	5	10	0
5.3 Airborne High-Power Microwave Weapon	0	0	0	0	0	0	0	0	0
5.4 Standoff Hypersonic Missile	0	0	0	0	0	0	0	0	0
5.5 Attack Microbots	0	0	0	0	0	0	0	10	0
5.6 Airborne Holographic Projector	0	0	0	0	0	0	0	0	0
5.7 Hybrid High-Energy Laser	0	0	0	0	0	0	0	0	0
6.0 SPACE-BASED WEAPONS									
6.1 Global Area Strike System	0	0	0	0	0	0	0	5	0
6.2 Space-Based Kinetic Energy Weapon	0	0	0	0	0	0	0	15	0
6.3 Space-Based High-Power Microwave Weapon	0	0	0	0	0	0	0	0	0
6.4 Space-Based High-Energy Laser System	0	0	0	0	0	0	0	0	0
6.5 Solar-Powered High-Energy Laser System	0	0	0	0	0	0	0	0	0
6.6 Solar Energy Optical Weapon	0	0	0	0	0	0	0	0	0
6.7 Asteroid Mitigation System	0	0	0	0	0	0	0	25	0
7.0 INDIVIDUAL INFORMATION SYSTEMS									
7.1 Spoken Language Translator	0	0	0	0	0	0	0	0	0
7.2 Personal Digital Assistant	0	0	0	0	0	0	0	0	0
7.3 Virtual Interaction Center	0	0	0	0	0	0	0	0	0
8.0 GLOBAL INFORMATION SYSTEMS									
8.1 Global Information Management System	3	5	0	2	1	3	1	0	0
8.2 Global Surveillance, Reconnaissance, and Targeting System	2	10	0	2	2	9	0	0	0
8.3 Sensor Microbots	2	2	2	0	0	2	2	10	0
8.4 Multiband Laser Sensor System	0	0	0	0	0	0	0	0	0
8.5 Asteroid Detection System	0	10	0	0	0	0	0	0	0
9.0 MISCELLANEOUS SYSTEMS									
9.1 Mobile Asset Repair Station	0	0	0	0	0	0	0	0	0
9.2 Weather Analysis and Modification System	0	0	0	0	0	0	10	0	0
9.3 Sanctuary Base	0	0	0	0	0	0	0	0	0

Table 5 (Continued)

SYSTEM	MCTL 9.2	MCTL 9.4	MCTL 9.5.1	MCTL 9.5.2	MCTL 9.5.4	MCTL 9.8	MCTL 10.1	MCTL 10.2
1.0 AIR VEHICLES (PILOTED)								
1.1 Hypersonic Attack Aircraft	25	0	0	0	35	0	0	0
1.2 Fotofighter	0	0	0	0	5	0	10	0
1.3 Container Aircraft	0	0	0	0	50	0	0	0
1.4 Lighter-than-Air Airlifter	0	0	0	0	40	0	0	0
1.5 Supersonic Airlifter	0	0	0	0	30	0	0	0
1.6 Stealth Airlifter	0	0	0	0	35	0	0	0
1.7 Global Transport Aircraft	0	0	0	0	30	0	0	0
2.0 AIR VEHICLES (UNINHABITED)								
2.1 Strike UAV	0	0	0	0	0	20	0	0
2.2 Reconnaissance UAV	0	0	0	0	0	0	0	0
2.3 Uninhabited Combat Air Vehicle	0	0	0	0	0	5	0	0
2.4 Precision Delivery System	0	0	0	0	0	0	0	0
2.5 UAV Mothership	0	0	0	0	15	0	10	5
2.6 Exfiltration Rocket	0	0	0	0	25	0	0	0
3.0 SPACE VEHICLES								
3.1 Orbital Maneuvering Vehicle	0	0	0	20	0	0	0	0
3.2 Orbital Combat Vehicle	0	0	0	20	0	0	5	0
3.3 Satellite Bodyguards	0	5	0	0	0	0	0	10
4.0 AIR AND SPACE VEHICLES								
4.1 Piloted SSTO Transatmospheric Vehicle	20	0	0	0	25	0	0	0
4.2 Uninhabited Air-Launched Transatmospheric Vehicle	0	0	0	0	20	0	0	0
5.0 AIR AND GROUND-BASED WEAPONS								
5.1 Adjustable Yield Munition	0	0	0	0	0	0	0	0
5.2 Advanced Air-to-Air Missile	0	0	0	0	0	0	0	0
5.3 Airborne High-Power Microwave Weapon	0	0	0	0	0	0	0	0
5.4 Standoff Hypersonic Missile	30	0	0	0	20	0	0	0
5.5 Attack Microbots	0	0	0	0	0	0	0	0
5.6 Airborne Holographic Projector	0	0	0	0	0	0	5	5
5.7 Hybrid High-Energy Laser	0	0	20	10	0	0	0	20
6.0 SPACE-BASED WEAPONS								
6.1 Global Area Strike System	5	0	5	0	10	0	0	15
6.2 Space-Based Kinetic Energy Weapon	0	0	0	0	0	0	0	0
6.3 Space-Based High-Power Microwave Weapon	0	0	5	0	0	0	0	0
6.4 Space-Based High-Energy Laser System	0	0	0	0	0	0	0	25
6.5 Solar-Powered High-Energy Laser System	0	0	0	0	0	0	0	15
6.6 Solar Energy Optical Weapon	0	0	50	0	0	0	0	10
6.7 Asteroid Mitigation System	0	0	0	55	0	0	0	0
7.0 INDIVIDUAL INFORMATION SYSTEMS								
7.1 Spoken Language Translator	0	0	0	0	0	0	0	0
7.2 Personal Digital Assistant	0	0	0	0	0	0	0	0
7.3 Virtual Interaction Center	0	0	0	0	0	0	0	0
8.0 GLOBAL INFORMATION SYSTEMS								
8.1 Global Information Management System	0	0	0	0	0	0	0	0
8.2 Global Surveillance, Reconnaissance, and Targeting System	0	0	0	0	0	0	0	0
8.3 Sensor Microbots	0	0	0	0	0	0	0	0
8.4 Multiband Laser Sensor System	0	0	0	0	0	0	25	10
8.5 Asteroid Detection System	0	0	20	0	0	0	0	30
9.0 MISCELLANEOUS SYSTEMS								
9.1 Mobile Asset Repair Station	0	0	0	0	0	0	0	0
9.2 Weather Analysis and Modification System	0	0	0	0	0	0	0	0
9.3 Sanctuary Base	0	0	0	0	0	0	5	0

Table 5 (Continued)

SYSTEM	MCTL 10.3	MCTL 11.1	MCTL 11.2	MCTL 11.4.2	MCTL 11.4.4	MCTL 12.1	MCTL 12.7	MCTL 13.3
1.0 AIR VEHICLES (PILOTED)								
1.1 Hypersonic Attack Aircraft	0	0	0	0	0	0	10	0
1.2 Fotofighter	5	10	0	0	0	0	0	0
1.3 Container Aircraft	0	0	0	0	0	0	0	0
1.4 Lighter-than-Air Airlifter	0	0	0	0	0	0	0	0
1.5 Supersonic Airlifter	0	0	0	0	0	0	0	0
1.6 Stealth Airlifter	0	0	0	0	0	0	0	0
1.7 Global Transport Aircraft	0	0	0	0	0	0	0	0
2.0 AIR VEHICLES (UNINHABITED)								
2.1 Strike UAV	0	0	0	0	0	30	0	0
2.2 Reconnaissance UAV	10	0	0	0	0	0	0	0
2.3 Uninhabited Combat Air Vehicle	5	0	0	0	0	0	10	0
2.4 Precision Delivery System	0	0	0	0	0	0	0	0
2.5 UAV Mothership	35	10	0	0	0	0	0	0
2.6 Exfiltration Rocket	0	0	0	0	0	0	35	0
3.0 SPACE VEHICLES								
3.1 Orbital Maneuvering Vehicle	25	0	0	0	0	0	0	0
3.2 Orbital Combat Vehicle	20	0	0	0	0	0	0	0
3.3 Satellite Bodyguards	20	30	0	0	0	0	0	0
4.0 AIR AND SPACE VEHICLES								
4.1 Piloted SSTO Transatmospheric Vehicle	0	0	0	0	0	0	25	0
4.2 Uninhabited Air-Launched Transatmospheric Vehicle	0	0	0	0	0	0	20	0
5.0 AIR AND GROUND-BASED WEAPONS								
5.1 Adjustable Yield Munition	0	0	0	0	0	0	100	0
5.2 Advanced Air-to-Air Missile	0	0	0	0	0	0	0	0
5.3 Airborne High-Power Microwave Weapon	30	0	60	0	0	0	0	0
5.4 Standoff Hypersonic Missile	0	0	0	0	0	0	30	0
5.5 Attack Microbots	15	0	0	0	0	0	5	0
5.6 Airborne Holographic Projector	10	0	0	0	0	0	0	0
5.7 Hybrid High-Energy Laser	10	40	0	0	0	0	0	0
6.0 SPACE-BASED WEAPONS								
6.1 Global Area Strike System	0	10	0	5	5	0	10	0
6.2 Space-Based Kinetic Energy Weapon	0	0	0	20	10	0	0	0
6.3 Space-Based High-Power Microwave Weapon	45	0	30	0	0	0	0	0
6.4 Space-Based High-Energy Laser System	10	25	0	0	0	0	0	0
6.5 Solar-Powered High-Energy Laser System	40	15	0	0	0	0	0	0
6.6 Solar Energy Optical Weapon	30	0	0	0	0	0	0	0
6.7 Asteroid Mitigation System	0	0	0	0	0	0	20	0
7.0 INDIVIDUAL INFORMATION SYSTEMS								
7.1 Spoken Language Translator	0	0	0	0	0	0	0	0
7.2 Personal Digital Assistant	20	0	0	0	0	0	0	0
7.3 Virtual Interaction Center	0	0	0	0	0	0	0	0
8.0 GLOBAL INFORMATION SYSTEMS								
8.1 Global Information Management System	0	0	0	0	0	0	0	0
8.2 Global Surveillance, Reconnaissance, and Targeting System	0	0	0	0	0	0	0	0
8.3 Sensor Microbots	15	0	0	0	0	0	0	0
8.4 Multiband Laser Sensor System	50	0	0	0	0	0	0	0
8.5 Asteroid Detection System	0	0	0	0	0	0	0	0
9.0 MISCELLANEOUS SYSTEMS								
9.1 Mobile Asset Repair Station	0	0	0	0	0	0	0	0
9.2 Weather Analysis and Modification System	0	0	20	0	0	0	0	0
9.3 Sanctuary Base	10	5	5	0	5	0	0	5

Table 6

Weighted Technology Scores
(All 43 Systems, AU Students Weights)

		GULLIVER'S TRAVAILS	ZAIBATSU	KING KHAN	DIGITAL CACO-PHONY	2015 CROSS-ROADS	HALFS and HALF-NAUGHTS
1.0	Materials	7.86	7.06	7.80	7.00	7.57	7.85
2.1	Auto of Ind Process, Sys, and Fact	0.56	0.51	0.55	0.51	0.54	0.56
2.2.1	Num Controlled Machine Tools	0.14	0.12	0.13	0.12	0.14	0.14
2.2.5	Robots, Controllers, & End Effectors	2.86	2.96	2.85	2.99	2.87	2.86
2.6	Micromechanical Devices	5.75	5.82	5.78	5.91	5.91	5.76
4.1.1	High-Performance Computing	6.12	6.28	6.12	6.28	6.12	6.12
4.1.2	Dynamic Training and Simulation	2.02	2.19	2.02	2.20	1.92	2.02
4.1.3	Signal Processing	1.85	2.10	1.86	2.08	1.85	1.86
4.1.4	Image Processing	3.90	3.97	3.90	3.92	3.83	3.90
4.1.6	Speech Processing	0.38	0.40	0.38	0.41	0.36	0.38
4.2.4	Hard Real-Time Systems	1.53	1.67	1.54	1.65	1.53	1.53
4.2.5	Data Fusion	5.18	5.80	5.19	5.74	5.22	5.18
4.2.9	Artificial Intelligence	4.34	4.73	4.33	4.78	4.31	4.34
4.3	Hybrid Computing	0.45	0.43	0.46	0.42	0.45	0.45
5.1	Transmission	2.50	2.68	2.51	2.70	2.52	2.50
5.3	Comm Network Mgmt and Control	0.92	1.06	0.92	1.08	0.88	0.92
5.4	C3I Systems	1.43	1.45	1.43	1.46	1.43	1.43
5.5	Information Security	1.38	1.52	1.39	1.52	1.37	1.38
6.1	Acoustic Systems	0.39	0.43	0.39	0.43	0.39	0.39
6.2	Optical Sensors	1.78	2.02	1.78	1.99	1.75	1.78
6.4	Electronic Combat	0.54	0.56	0.54	0.57	0.54	0.54
6.6	Magnetometers	0.28	0.31	0.28	0.31	0.28	0.28
6.7	Gravity Meters	0.14	0.18	0.14	0.18	0.14	0.14
6.8	Radar	1.44	1.61	1.44	1.60	1.42	1.44
6.9	Other Sensor	0.88	0.93	0.87	0.93	0.87	0.88
7.3	Vehicle and Flight Control	3.94	3.46	3.90	3.48	3.83	3.93
9.1	Gas Turbine Propulsion Systems	1.23	0.87	1.20	0.85	1.11	1.23
9.2	Ramjet, Scramjet, and CC Engines	2.09	2.02	2.10	1.99	2.07	2.09
9.4	Rockets	0.11	0.14	0.11	0.14	0.12	0.11
9.5.1	Spacecraft Structures	1.60	1.60	1.61	1.60	1.71	1.60
9.5.2	Nonchem, High-Isp Propulsion	1.31	1.41	1.31	1.43	1.38	1.31
9.5.4	Aircraft High-Performance Structures	6.91	6.31	6.86	6.24	6.54	6.91
9.8	Other Propulsion	0.56	0.49	0.57	0.49	0.57	0.56
10.1	Lasers	1.33	1.27	1.33	1.26	1.30	1.33
10.2	Optics	3.64	3.80	3.66	3.71	3.78	3.64
10.3	Power Systems	8.81	8.84	8.84	8.95	9.11	8.81
11.1	High-Energy Laser Systems	4.15	4.29	4.18	4.23	4.37	4.15
11.2	High-Power Radio Frequency Sys	2.33	2.04	2.35	2.16	2.50	2.33
11.4.2	Kinetic Energy Projectiles	0.59	0.52	0.60	0.52	0.65	0.59
11.4.4	Kinetic Energy Platform Mgmt	0.68	0.64	0.69	0.64	0.71	0.68
12.1	Warheads, Ammunition, & Payloads	0.54	0.40	0.54	0.39	0.55	0.54
12.7	Mil Explosives (Energetic Material)	5.27	4.89	5.26	4.89	5.22	5.27
13.3	CBW Defensive Systems	0.28	0.27	0.28	0.27	0.27	0.28

Table 7

Weighted Technology Scores
(Top 11 Systems, AU Students Weights)

		GULLIVER'S TRAVAILS	ZAIBATSU	KING KHAN	DIGITAL CACO-PHONY	2015 CROSS-ROADS	HALFS and HALF-NAUGHTS
1.0	Materials	6.10	6.01	6.08	6.01	6.02	6.10
2.1	Auto of Ind Process, Sys, and Fact	0.65	0.58	0.65	0.57	0.62	0.65
2.2.1	Num Controlled Machine Tools	0.00	0.00	0.00	0.00	0.00	0.00
2.2.5	Robots, Controllers, & End Effectors	3.39	3.14	3.39	3.16	3.37	3.39
2.6	Micromechanical Devices	6.66	6.38	6.69	6.54	6.76	6.66
4.1.1	High-Performance Computing	5.21	5.23	5.21	5.24	5.24	5.21
4.1.2	Dynamic Training and Simulation	1.45	1.47	1.45	1.47	1.42	1.45
4.1.3	Signal Processing	3.54	3.67	3.54	3.63	3.51	3.54
4.1.4	Image Processing	4.41	4.48	4.41	4.44	4.35	4.41
4.1.6	Speech Processing	0.00	0.00	0.00	0.00	0.00	0.00
4.2.4	Hard Real-Time Systems	2.88	2.90	2.89	2.85	2.90	2.88
4.2.5	Data Fusion	8.39	8.80	8.38	8.78	8.31	8.39
4.2.9	Artificial Intelligence	4.65	4.76	4.65	4.80	4.63	4.65
4.3	Hybrid Computing	0.00	0.00	0.00	0.00	0.00	0.00
5.1	Transmission	3.93	4.11	3.92	4.13	3.88	3.93
5.3	Comm Network Mgmt and Control	0.93	1.04	0.93	1.04	0.91	0.93
5.4	C3I Systems	1.52	1.63	1.53	1.66	1.53	1.52
5.5	Information Security	2.33	2.54	2.33	2.55	2.28	2.33
6.1	Acoustic Systems	0.59	0.66	0.59	0.66	0.58	0.59
6.2	Optical Sensors	2.87	3.12	2.87	3.11	2.78	2.87
6.4	Electronic Combat	0.95	0.94	0.95	0.95	0.94	0.95
6.6	Magnetometers	0.46	0.52	0.46	0.52	0.45	0.46
6.7	Gravity Meters	0.33	0.37	0.33	0.37	0.32	0.33
6.8	Radar	2.51	2.72	2.50	2.71	2.42	2.51
6.9	Other Sensor	1.35	1.40	1.35	1.39	1.30	1.35
7.3	Vehicle and Flight Control	1.92	1.86	1.92	1.92	2.00	1.92
9.1	Gas Turbine Propulsion Systems	0.00	0.00	0.00	0.00	0.00	0.00
9.2	Ramjet, Scramjet, and CC Engines	1.90	1.94	1.89	1.95	1.93	1.90
9.4	Rockets	0.00	0.00	0.00	0.00	0.00	0.00
9.5.1	Spacecraft Structures	0.49	0.45	0.49	0.45	0.50	0.49
9.5.2	Nonchem, High-Isp Propulsion	0.00	0.00	0.00	0.00	0.00	0.00
9.5.4	Aircraft High-Performance Structures	4.14	4.24	4.12	4.27	4.20	4.14
9.8	Other Propulsion	0.48	0.47	0.48	0.47	0.47	0.48
10.1	Lasers	0.65	0.58	0.65	0.57	0.62	0.65
10.2	Optics	4.60	4.32	4.62	4.22	4.78	4.60
10.3	Power Systems	7.53	7.10	7.56	7.03	7.67	7.53
11.1	High-Energy Laser Systems	4.77	4.44	4.79	4.34	4.90	4.77
11.2	High-Power Radio Frequency Sys	0.65	0.58	0.65	0.57	0.62	0.65
11.4.2	Kinetic Energy Projectiles	0.49	0.45	0.49	0.45	0.50	0.49
11.4.4	Kinetic Energy Platform Mgmt	1.14	1.03	1.14	1.02	1.13	1.14
12.1	Warheads, Ammunition, & Payloads	0.00	0.00	0.00	0.00	0.00	0.00
12.7	Mil Explosives (Energetic Material)	5.46	5.52	5.44	5.58	5.53	5.46
13.3	CBW Defensive Systems	0.65	0.58	0.65	0.57	0.62	0.65

Table 8

Weighted Technology Scores
(All 43 Systems, Alternate Futures Team Weights)

		GULLIVER'S TRAVAILS	ZAIBATSU	KING KHAN	DIGITAL CACO-PHONY	2015 CROSS-ROADS	HALFS and HALF-NAUGHTS
1.0	Materials	8.34	6.97	7.69	5.97	7.58	7.17
2.1	Auto of Ind Process, Sys, and Fact	0.55	0.31	0.60	0.34	0.48	0.52
2.2.1	Num Controlled Machine Tools	0.12	0.03	0.17	0.02	0.07	0.12
2.2.5	Robots, Controllers, & End Effectors	2.68	2.85	2.88	2.84	2.76	2.91
2.6	Micromechanical Devices	5.88	6.67	5.97	6.72	6.25	6.38
4.1.1	High-Performance Computing	5.90	5.78	6.06	6.33	6.07	6.07
4.1.2	Dynamic Training and Simulation	1.90	1.32	1.90	2.43	1.96	2.05
4.1.3	Signal Processing	1.80	2.38	1.90	2.41	1.90	1.89
4.1.4	Image Processing	4.05	3.76	3.89	3.95	3.83	3.90
4.1.6	Speech Processing	0.33	0.17	0.35	0.35	0.29	0.34
4.2.4	Hard Real-Time Systems	1.50	1.74	1.52	1.96	1.64	1.58
4.2.5	Data Fusion	5.05	6.59	5.42	6.43	5.29	5.38
4.2.9	Artificial Intelligence	4.02	4.30	4.29	4.93	4.07	4.43
4.3	Hybrid Computing	0.49	0.43	0.44	0.46	0.53	0.44
5.1	Transmission	2.52	2.99	2.53	3.10	2.63	2.67
5.3	Comm Network Mgmt and Control	0.82	0.79	0.86	1.25	0.84	0.92
5.4	C3I Systems	1.48	1.54	1.39	1.65	1.51	1.54
5.5	Information Security	1.39	1.64	1.36	1.81	1.46	1.48
6.1	Acoustic Systems	0.37	0.47	0.41	0.51	0.39	0.42
6.2	Optical Sensors	1.77	2.36	1.87	2.28	1.84	1.84
6.4	Electronic Combat	0.56	0.73	0.57	0.64	0.60	0.59
6.6	Magnetometers	0.26	0.33	0.29	0.35	0.28	0.30
6.7	Gravity Meters	0.13	0.21	0.15	0.22	0.14	0.15
6.8	Radar	1.43	1.91	1.52	1.82	1.51	1.49
6.9	Other Sensor	0.88	1.06	0.94	0.95	0.87	0.89
7.3	Vehicle and Flight Control	4.08	3.19	3.99	2.67	3.45	3.65
9.1	Gas Turbine Propulsion Systems	1.44	0.68	1.15	0.37	0.96	0.94
9.2	Ramjet, Scramjet, and CC Engines	2.27	2.19	2.10	1.93	2.16	2.00
9.4	Rockets	0.09	0.13	0.11	0.13	0.09	0.11
9.5.1	Spacecraft Structures	1.51	1.45	1.54	1.48	1.59	1.65
9.5.2	Nonchem, High-Isp Propulsion	1.03	1.06	1.35	1.02	1.01	1.30
9.5.4	Aircraft High-Performance Structures	7.28	6.14	6.58	5.27	6.44	6.08
9.8	Other Propulsion	0.64	0.52	0.53	0.50	0.68	0.60
10.1	Lasers	1.34	1.17	1.40	1.18	1.34	1.24
10.2	Optics	3.53	4.13	3.65	3.97	3.90	3.65
10.3	Power Systems	8.51	9.13	9.08	9.05	8.98	9.15
11.1	High-Energy Laser Systems	3.92	4.60	4.04	4.64	4.63	4.22
11.2	High-Power Radio Frequency Sys	2.37	1.90	2.33	2.05	2.62	2.66
11.4.2	Kinetic Energy Projectiles	0.59	0.51	0.53	0.56	0.75	0.63
11.4.4	Kinetic Energy Platform Mgmt	0.70	0.62	0.64	0.70	0.83	0.70
12.1	Warheads, Ammunition, & Payloads	0.63	0.33	0.48	0.36	0.66	0.56
12.7	Mil Explosives (Energetic Material)	5.54	4.68	5.23	4.11	4.80	5.09
13.3	CBW Defensive Systems	0.30	0.25	0.27	0.30	0.33	0.28

Table 9

Weighted Technology Scores (Top 11 Systems, Alternate Futures Team Weights)

		GULLIVER'S TRAVAILS	ZAIBATSU	KING KHAN	DIGITAL CACO-PHONY	2015 CROSS-ROADS	HALFS and HALF-NAUGHTS
1.0	Materials	5.89	5.58	6.08	5.43	5.84	5.76
2.1	Auto of Ind Process, Sys, and Fact	0.71	0.44	0.61	0.55	0.72	0.61
2.2.1	Num Controlled Machine Tools	0.00	0.00	0.00	0.00	0.00	0.00
2.2.5	Robots, Controllers, & End Effectors	3.51	2.86	3.33	3.08	3.53	3.42
2.6	Micromechanical Devices	7.05	6.73	6.64	6.98	7.09	7.35
4.1.1	High-Performance Computing	4.98	4.96	5.15	5.09	5.07	5.15
4.1.2	Dynamic Training and Simulation	1.49	1.31	1.41	1.61	1.47	1.50
4.1.3	Signal Processing	3.60	3.90	3.61	3.72	3.52	3.49
4.1.4	Image Processing	4.55	4.71	4.45	4.53	4.46	4.35
4.1.6	Speech Processing	0.00	0.00	0.00	0.00	0.00	0.00
4.2.4	Hard Real-Time Systems	2.92	2.92	2.86	3.02	2.98	2.86
4.2.5	Data Fusion	8.40	9.14	8.57	8.99	8.13	8.45
4.2.9	Artificial Intelligence	4.72	4.66	4.67	5.04	4.63	4.87
4.3	Hybrid Computing	0.00	0.00	0.00	0.00	0.00	0.00
5.1	Transmission	3.97	4.29	3.97	4.30	3.86	4.06
5.3	Comm Network Mgmt and Control	0.89	1.02	0.92	1.13	0.87	0.96
5.4	C3I Systems	1.53	1.72	1.54	1.83	1.50	1.68
5.5	Information Security	2.31	2.58	2.32	2.75	2.25	2.42
6.1	Acoustic Systems	0.58	0.64	0.59	0.73	0.56	0.63
6.2	Optical Sensors	2.87	3.25	2.93	3.18	2.71	2.87
6.4	Electronic Combat	1.04	1.10	0.96	0.97	1.02	0.99
6.6	Magnetometers	0.45	0.51	0.46	0.57	0.43	0.48
6.7	Gravity Meters	0.31	0.37	0.33	0.40	0.31	0.34
6.8	Radar	2.52	2.86	2.57	2.73	2.37	2.48
6.9	Other Sensor	1.43	1.53	1.42	1.35	1.31	1.32
7.3	Vehicle and Flight Control	1.87	1.95	1.95	1.87	1.90	2.07
9.1	Gas Turbine Propulsion Systems	0.00	0.00	0.00	0.00	0.00	0.00
9.2	Ramjet, Scramjet, and CC Engines	1.62	1.69	1.91	1.63	1.63	1.76
9.4	Rockets	0.00	0.00	0.00	0.00	0.00	0.00
9.5.1	Spacecraft Structures	0.47	0.42	0.45	0.43	0.53	0.48
9.5.2	Nonchem, High-Isp Propulsion	0.00	0.00	0.00	0.00	0.00	0.00
9.5.4	Aircraft High-Performance Structures	3.51	3.71	4.18	3.56	3.54	3.83
9.8	Other Propulsion	0.52	0.55	0.48	0.49	0.51	0.49
10.1	Lasers	0.71	0.44	0.61	0.55	0.72	0.61
10.2	Optics	4.66	4.52	4.50	4.32	5.02	4.46
10.3	Power Systems	8.00	7.66	7.61	7.29	8.13	7.61
11.1	High-Energy Laser Systems	4.89	4.54	4.66	4.43	5.21	4.59
11.2	High-Power Radio Frequency Sys	0.71	0.44	0.61	0.55	0.72	0.61
11.4.2	Kinetic Energy Projectiles	0.47	0.42	0.45	0.43	0.53	0.48
11.4.4	Kinetic Energy Platform Mgmt	1.18	0.87	1.06	0.98	1.25	1.08
12.1	Warheads, Ammunition, & Payloads	0.00	0.00	0.00	0.00	0.00	0.00
12.7	Mil Explosives (Energetic Material)	4.97	5.25	5.53	4.95	4.97	5.29
13.3	CBW Defensive Systems	0.71	0.44	0.61	0.55	0.72	0.61

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